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### **Announcement**

The *Publications Puget Sound Biological Station* of the University of Washington appear at irregular intervals. The articles are numbered consecutively from the beginning of the Publications. The pages and plates are consecutive throughout a volume. The subscription price is \$3.50 per volume of about 400 pages. For information address Dr. T. C. Frye, University of Washington, Seattle, Washington.

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# **Experiments and Observations on the Behavior of Marine Fishes Toward the Hydrogen-ion Concentration of the Sea-Water in Relation to Their Migratory Movements and Habitat.\***

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## **A. INTRODUCTION**

For many years various explanations have been offered as to the cause of the migration of fishes. Some are based upon experimentation and observation while others are purely speculative. The salmon, especially, has been the subject of much conjecture, the view being that this fish has a homing instinct, as it is generally believed that the salmon always returns to spawn in the same river from whence it came. From the study of marked fishes Calderwood (1907) claims this to be true with few exceptions. The work of Dahl (1911), however, seems to indicate that this does not always hold. The voice of what remains of the purely speculative view is sounded by Paton (1898) who says, "when on the rich marine feeding grounds as great a store of nourishment as the body can carry has been accumulated, the fish returns to its native element".

In more recent years workers have turned more to direct observations and laboratory experimentation. This has led to various suppositions. Esdaile (1913) and others believe that temperature controls the migration of the salmon. Johnstone (1908) claims that temperature and salinity are determining factors in the movements of the herring. Pettersson (1909) holds that temperature is a factor, while Paulsen (1906) points to the plankton, especially the crustacean *Calanus finmarchicus*, as an influence dominating the movements of this same fish. Roule (1913, see bibliography) made extensive studies throughout the entire year of variations in the conditions of the water of the sea, estuaries and rivers frequented by migratory fishes, and attempted to correlate the variation in temperature and oxygen content of the water with migratory movements of fishes. These studies have led him to suggest that their movements are tropic in nature. The salmon, he says, always moves in the direction of the higher oxygenated water regardless of the temperature and salinity. The tunny

\*Studies from the Department of Zoology, The University of Nebraska, No. 128.

is supposed to be thermotropic. Shelford and Powers (1915) suggested that the reaction of the water had perhaps a dominant influence over the movements of such fishes as the herring and salmon.

The present work was undertaken to determine whether or not the fishes reacted positively to a specific range of acidity or alkalinity of the sea-water or whether the migratory movements were merely a drift at certain seasons of the year toward water having a more alkaline or acid reaction; and if this factor could be applied to the movements of fishes having a less migratory habit, in choosing their place of abode. In this work the writer has not depended wholly upon laboratory experimentation or field observation but has attempted to correlate the two. This method was applied hoping to meet the objections used as argument against purely laboratory experimentation as well as against field observation alone; but it was primarily used because the author believes that the solution of the problem can be obtained only through the correlation of the two. Neither alone will suffice. In the laboratory one factor at a time, or if possible different combinations of factors, should be studied. In the field all factors should be determined and not merely one or two, such as temperature and salinity, which has too often been the case in field observations in general. The results of the laboratory experimentation and field observations recorded in this paper show a close correlation.

## B. METHODS AND MATERIALS

The methods used in this work for determining the conditions of the sea-water in the field have already been described by Powers (1920), the laboratory method by Shelford and Powers (1915), and the particular tank used, by Shelford (1918). The difference in alkalinity and acidity, or the hydrogen-ion concentration at the two ends of the experimental trough, was controlled by the addition of very small amounts of either very strongly alkaline or very strongly acid sea-water from a large carboy, to the inflow at the right hand end of the experimental trough by means of a mixing bottle. The temperature of the gradient of hydrogen-ion concentration thus formed was kept the same throughout without difficulty by an addition of an equal amount of untreated sea-water from a second carboy to the opposite inflow.

The alkaline sea-water was prepared during the summer of 1918 by the addition of sodium carbonate and during the summer of 1919 by the addition of sodium hydroxide. For the acid sea-water carbon dioxide was used in 1918 and hydrochloric acid in 1919. By the

addition of the modified sea-water to the experimental sea-water, the only modification that took place, different from that going on in the sea, when the hydrogen-ion concentration varies under natural conditions over the same range, is a very slight increase in the relative amount of chlorine when sea-water acidulated with hydrochloric acid is added, and of sodium when the alkaline sea-water is added. In addition to the slight increase in the relative amount of sodium when the alkaline sea-water is added there are also very slight decreases in the relative amounts of magnesium and calcium. In the preparation of the alkaline sea-water contained in the carboy perhaps a sufficient amount of sodium carbonate or sodium hydroxide was added to bring down most of the magnesium and calcium (Hass 1916), which was allowed to settle as a white precipitate before the water was used. There was never a precipitate on the addition of the alkaline sea-water to the untreated sea-water in the mixing bottle. Thus the alterations in the relative amounts of chlorine, sodium, magnesium, and calcium would in all cases be very slight. The relative total amounts would be extremely small as compared with relative total amounts of these substances in the water of the Sound and adjacent sea, or perhaps in different portions of the Sound as you pass toward the sea proper. The water of the Sound is very much diluted. In no case could the relative amount of chlorine, sodium, magnesium or calcium in the two ends of the experimental trough be considered as controlling factors.

The fishes used in these experiments were herring (*Clupea pallasii* Cuv. and Val.), about 6 cm. in length; the smolt of the silver salmon (*Oncorhynchus kisutch* Wal.), about 7 cm. long, seined in the open water; the viviparous perch (*Cymatogaster aggregatus* Gib.), between 10 and 15 cm. in length, taken from a small lagoon; an unidentified species; *Myoxocephalus polyacanthocephalus* Pal.; *Oligocottus borealis* Jor. and Sny.; *Leptocottus armatus* Gir.; *Neoliparis fissuratus* Star.; *Blepsias cirrhosus* Pal.; *Gasterosteus cataphractus* Pal.; and *Pallasina air* Star. The last was secured from among the eel-grass (*Zostera marina*); all the others were seined mainly from among the vegetation near the shore.

## C. EXPERIMENTAL AND FIELD OBSERVATIONS

### 1. Explanation of plates

The graphs include representative experiments performed during the summers of 1918 and 1919. The method of recording experimental observations by means of graphs has been described by Shelford and his students. The graphs have been arranged on the plates so as to show a



gradual increase in the hydrogen-ion concentration, i. e., a decrease in the pH, from left to right in a series of experiments performed on a given species of fish. Graphs 1 and 5 on plate 1, 1 and 4 on plate 2, 1, 3, 5, and 6 on plate 3, and 1 to 5 on plate 4 have been reversed, i. e., the image drawn, to fit in with this scheme. This also gives a key as to whether alkaline or acid water was added in the experiment. Both were always added at the right hand end of the experimental trough. Thus, all graphs that have not been reversed represent experiments in which acid sea-water was used and vice versa.

## 2. Reactions of fishes to gradients of hydrogen-ion concentration

### a. Herring (*Culpea pallasii* Cuv. and Val.)

Twenty experiments were made with the herring to determine their reaction to a gradient of hydrogen-ion concentration. The graphs of plate 1, and the first three and last one of plate 2, are typical of these experiments. By an examination of plate 1 it is seen that the herring do not react so markedly to gradients of hydrogen-ion concentration of the water with a pH greater than 7.75 or below 7.58, provided that the gradient is not very steep (graphs 1, 2, 6, and 7, on plate 1). They select a hydrogen-ion concentration a little below 7.73 and above 7.68 pH, provided that this range is within that of the gradient used (graphs 3 to 5 on plate 1, and 2 and 7 on plate 2). On the other hand, the herring do react to a gradient of hydrogen-ion concentration above a pH of 7.73 and below 7.58, when the gradient is rather steep (graphs 1 and 3 on plate 2). They then select the hydrogen-ion concentration nearest 7.73 to 7.68 pH.

Experiment 5, graph 4 on plate 1, shows the marked reaction of the herring to a very slight variation in the hydrogen-ion concentration. In the beginning of the experiment the hydrogen-ion concentration at the two ends of the trough were 7.73+ and 7.68 pH. After the experiment had continued for about ten or twelve minutes the keeper of the Station started the pump, which added fresh sea-water to the supply tank and caused a rise of the pH throughout the experimental trough to 7.78 and 7.73— at the two ends. Almost immediately the herring showed an avoidance of the portion of the gradient with a pH above 7.73. Experiment 26, graph 2 on plate 2 is still more interesting in showing the extreme sensitiveness of this fish to slight variations of the pH in the gradient. At the beginning of the experiment the pH at the two ends of the gradient was respectively 7.88 and 7.48, and at the middle 7.68. The herring during the first part of the experiment selected the half with the higher pH, i. e.,

between 7.88 and 7.68. At the end of  $8\frac{1}{2}$  minutes the fish suddenly changed halves in the trough, i. e., it began showing a preference for the opposite half, or rather that end. After about 15 minutes the experiment was discontinued in order to take the pH. It was found that the pH at the two ends was respectively 7.88 and 7.68+, while at the middle it was only 7.68—. After investigation it was found that the inlet from the acid sea-water had almost ceased flowing thus allowing the pH at the acid or lower pH end of the trough to be raised above that at the center. The herring throughout the experiment was perhaps selecting water with a pH of about 7.73— to 7.68+.

b. Silver salmon smolt (*Oncorhynchus kisutch* Wal.)

Experiments 62, 50, and 52 made with the silver salmon smolt are shown in graphs 4 to 6 on plate 2. From these experiments it is seen that the silver salmon smolt selects the portion of the gradient having a hydrogen-ion concentration nearest a pH of about 7.98. Unlike the herring this fish selected a particular portion of the gradient in all experiments.

c. Viviparous perch (*Cymatogaster aggregatus* Gib.)

Graphs 1 to 5 on plate 3 represent typical experiments made with the viviparous perch. Without exception this fish showed a preference for the portion of the gradient with a pH of about 7.95 to about 7.83 or the pH nearest this. The range of pH selected by the viviparous perch was greater than was that of either the herring or silver salmon smolt. In no case did this fish select a pH above 7.95 or below 7.83 provided the gradient included either of these extremes.

d. An unidentified species

Five experiments were made with an unidentified species of fish taken from among the vegetation, with gradients not differing more than 0.3 pH between the two ends of the experimental trough, over a range from 8.3 to 7.68 pH. As far as could be judged this fish showed no preference for any specific range of hydrogen-ion concentration (graphs 6 and 7 on plate 3).

e. *Myoxocephalus polyacanthocephalus* Pal.

Three experiments were made with this fish, of which graph 1 on plate 4 is typical. It showed little tendency to move from one end of the trough to the other but remained almost perfectly quiet unless poked.

After being poked it moved only a short distance when it again came to rest.

f. *Oligocottus borealis* Jor. and Sny.

In the four experiments made with *O. borealis*, it showed little more tendency to move in the gradient (graph 2 on plate 4) than did the preceding species though the gradient was made rather steep.

g. *Leptocottus armatus* Gir.

Five experiments were made with *L. armatus* in which it showed little tendency to move without being poked (graph 3 on plate 4). After being poked there was no indication that it selected any specific range of pH when again coming to rest.

h. *Neoliparis fissuratus* Star.

Five experiments were made with *N. fissuratus*. This fish moved about nosing the sides of the trough for a short time, after which it attached itself by means of the ventral disc. After it had become attached it would not move unless poked sufficiently hard to be detached. It would then move about as before and soon again attach itself. The portion of the trough at which it became attached seemed to have no relation to the pH of the water (graph 4 on plate 4). Two experiments were performed in which it was attempted to force the fish to detach themselves from the side of the trough by decreasing the pH. The pH was lowered to a point between 6.5 and 5.5. They did not move but died without ever detaching.

i. *Pallasina aix* Star.

Three experiments were made with *P. aix*. This fish showed no preference for any specific range of hydrogen-ion concentration. It moved very little, but showed great sensitiveness to an increased hydrogen-ion concentration, dying when the pH was decreased to about 7.35 to 7.15.

j. *Blepsias cirrhosus* Pal.

Two experiments were made with *B. cirrhosus*, one of which is shown in graph 6 on plate 4. This fish showed a greater tendency to move about in the gradient trough but showed no tendency to select a specific range of pH.

TABLE 1. Showing the condition of the sea-water in the vicinity of Friday Harbor where herring and salmon smolt were observed and places which they were known to frequent

Date	Time	pH	Temperature, Centigrade	Remarks
6/23*	8:00-8 30	7 98-7 98	10 4-11 1°	No fish seen at time Herring and salmon smolt taken in same haul 1½ hrs. before
6/23*	8 40	7 88	10 2°	Over school of herring
6/24*	5 40	7 65	11 2°	No fish seen
6/25*	2 30 8 00	7 57-7 55	11 2 9 5°	No fish seen
6/25*	8 15	7 72	10 4°	Small embayment Thousands of herring seen Only place found
6/26*	3 30 8 05	7 93-7 82	12 4 10°	No fish seen
6/27*	4 30 8 45	8 38-7 58	14 6-9 3°	No fish seen
6/28*	2 30	7 71	11°	False Bay Large school of herring Played for long period
6 28*	7 00	7 88	9 6°	Same place No fish seen
6 30*	(8 00)	7 73		Herring in all parts of channel near station
6 30*	(9 00)	7 70		Few minutes after fish seemed to have disappeared from open water
6 30*	(9 10)	7 73		Near Brown Island and vegetation Herring still playing
6/30*	2 30	7 68	10°	No fish seen
7 1*	11 00 11 45	8 18 7 74	12 3 9 9°	No fish seen
7 5†	5 00 6 00	8 18 7 77	13 10°	No fish seen
7 6†	4 00 5 00	7 63-7 77	9 8°	No fish seen
7 7*	4 15 8 10	7 98 7 95	12 6 10 2°	No fish seen
7 7*	4 00	7 76	11 9°	Near Station where herring had been seen 10 minutes before
7 8*	9 00 9 50	8 18 7 98	11 1-8 4°	No fish seen
7 9*	3 30 8 25	7 98 7 76	11 8 10 2°	No fish seen
7 10*	8 20 9 15	8 18 7 76	11 6 9°	No fish seen
7 10*	9 10	7 76	11 1°	Over school of herring
7 10*	9 15	7 78	11 1°	Number of herring short distance away
7 11*	2 00 8 45	8 18 7 88	13 4 11 6°	No fish seen
7 12*	(8 35)	7 68	11 8°	Herring had been seen at (7 00) and again at this time
7 12*	(9 35) 9 00	7 90 7 55	12 6 11 6°	No fish seen in bay
7 13*	9 05 9 30	7 96 7 85	12 9 5°	No fish seen
7 14*	7 30 9 30	7 88 7 85		No fish seen
7 14*	7 35	7 82		Number of herring seen at station
7 10†	2 00 4 30	8 12 7 88	13 8 12 2°	No fish seen
7 17*	2 00 5 30	8 16 7 95	14 5 14°	No herring seen
7 17*	6 30	8 08 7 98	14°	Salmon smolt taken in the bay
7 18*	(6 30)	7 93	12 1°	No fish seen at docks at station
7 21*	(9 10) 5 30	8 14 7 77	14 7 13 2°	22 determinations made No fish seen
7 21*	(9 35)	8 08	14 7°	Near beach School of salmon smolt
7 21*	(11 10)	7 90	14 1°	A very large school of herring near shore Played for 25 min and was there when observer left
7 21*	11 15 11 25	8 02 7 96	14 7 14 3°	Out from beach on two sides where there was school of herring
7 21*	1 50 2 00	7 84 7 82	14 3	Herring playing by thousands at docks at station
7 21*	1 55	7 90		Five meters below herring
7 21*	3 10	7 93		Same place Not a fish seen
7 21*	5 30	7 78	13 8	A number of herring seen
7 22*	(10 25) 4 40	6 10 7 86	14 4 13 2°	No fish seen
7 22*	1 50	8 03	14 3°	Same place and time herring were seen day before and not a fish to be seen
7 23*	(5 30)	7 88 7 85	12 8°	At docks at station One school of herring seen
7 23*	(6 15)	7 83	12 8°	Same place no fish seen
7/23*	(6 15) 4 00	8 03 7 83	13 4 12 8°	No fish seen

### 3. Explanation of table

The table gives field observations of the condition of the sea-water in the vicinity of the Puget Sound Biological Station during the summer of 1919, both where fishes were found, and where no fishes were

observed although they were known to be common. The oxygen content of the water is not included in this table since the hydrogen-ion concentration and the oxygen content of the water could not be correlated in any way in their variations (Powers 1920); and it was found that there was more or less correlation between the appearance of the salmon smolt and herring, and the hydrogen-ion concentration of the water. For the oxygen content of the water see the tables in Powers (1920). The asterisks (\*) after the date indicate clear weather, the dagger (†) cloudy weather, and the double dagger (‡) cloudy weather and rain. Figures in parentheses are forenoon.

#### 4. *Discussion of data*

It was found by field observation that there were daily variations both of the pH in any one locality of the Sound and variations at any one time in different portions of the Sound. This afforded an excellent opportunity to determine whether or not the herring and salmon smolt occurred in the vicinity of the Station and at different localities in this vicinity irrespective of the hydrogen-ion concentration of the sea-water. At only one time, June 23, were the herring found in water with a pH above 7.90 and they were never found in water with a pH below 7.71. On this occasion only, were the herring and salmon smolt found at the same place and time. They were taken with a 12-meter seine which had been dragged 50 to 70 meters through the water. However, the haul was composed mostly of salmon smolt, there being only a few herring.

The greatest number of herring, also, including the largest and greatest number of schools appearing at any one time, were observed in water with a pH varying from 7.76 to 7.73. At times the herring appeared over the greater portion of Newhall Bay (station D, map, Powers 1920). At such times the pH of the embayment was more nearly uniform than when these fish appeared locally. The salmon smolt were never observed in water with a pH below 7.98 and above 8.08. Their visits to the vicinity of the station were far less frequent than those of the herring.

For several days, July 1 to 7, when the pH of the sea-water in the vicinity of the station where herring were taken most often averaged rather high throughout the day, no herring were observed at all. This was also true when the pH was rather low. As a rule when the fish were observed they appeared in great numbers.

Very interesting observations were made on June 25 and July 21. On June 25 the average pH of the open waters was rather low, 7.57 to

7.55. In a small embayment at the south end of Brown Island (map, Powers 1920), at about 8:15 p. m., many thousands of herring were congregated. The pH of the water at this place was found to be 7.72. On July 21, about 11:00 a. m., a very large school of herring was found playing at the southwest end of Brown Island. They were watched for more than 25 minutes and were still playing at the same place when the observer left. The pH of this embayment was found to be 7.90 while the pH out from the embayment on the two sides was from 8.02 to 7.96. One would judge from these observations that the fish had been driven from the open water to the embayments which had a more compatible hydrogen-ion concentration than that of the open water.

Herring did not occur in all waters that had a pH of 7.76 to 7.73, nor the salmon smolt in all waters having a pH of 7.98 to 8.08. However, this is neither positive nor negative evidence. The positive evidence is that these fishes when found did not occur in water having a pH outside these limits.

On June 30 at 8:00 a. m. the small channel between Brown Island and the Biological Station seemed to be alive with schools of herring. The pH was just about 7.73. At 9:00 a. m., five minutes after the last school had disappeared from the main portion of the channel the pH of the water was 7.70. At this same time two or three large schools were observed near Brown Island and the vegetation, where the pH was still 7.73. These also later disappeared. On July 17 salmon smolt were taken in Newhall Bay where the pH was from 8.08— to 7.98. There were only one or two schools seen, and as far as known there were no herring present in the bay. On July 21 salmon smolt were found in water with a pH of 8.06, and herring in water with a pH of 7.90.

#### D. DISCUSSION

When the experimental results are compared with the field observations it is found that the two agree comparatively well. The herring and salmon smolt were found in the Sound always in water with a pH at or near the pH selected by each of these fishes in a hydrogen-ion concentration gradient. The pH of the water where each of these fishes was found had a tendency to be just a little higher than that selected by the fishes in the experimental gradient. The viviparous perch used in these experiments were all taken from a small lagoon which was land-locked below about half tide. The pH of the water of this lagoon in daylight, at any rate during the time that it was land-locked, rose very high, 7.89 to 8.62. This fish was able to tolerate a rather high pH in

nature. So the selection of a specific range of pH was not altogether a matter of tolerance. The presence of this fish in the lagoon might be explained by the fact that at high tide, both when the tide was going out and when coming in, at any rate during daylight, there was a rather steep gradient of pH from the water of the bay to the mouth of the lagoon (table 6, Powers 1920). When once this fish got into the lagoon it was unable to get out at low tide. The salmon smolt select a higher pH than the herring. This is shown to the greatest advantage by graphs 6 and 7 on plate 2, which have been placed purposely side by side. Again, the selection of a definite pH by the herring is not a matter of tolerance as it will thrive for a considerable time in fresh-water (McIntosh 1885), is able to live in brackish water (Lydekker 1896), and can be kept in the laboratory for a long period (Williams 1917).

All other fishes tested showed no tendency, so far as could be judged from the experiments, to select definite ranges of hydrogen-ion concentrations. These fishes were found in definite habitats irrespective of the pH of the water. Thus it seems that bottom forms and those living among the vegetation select their habitats by factors other than the hydrogen-ion concentration of the water.

When the observations of Roule (see bibliography) are considered, it will be recalled that the salmon always migrated in the direction of higher oxygenated water. He concluded that the fish were driven by a demand of the respiratory function, that is, by oxygen want. When the literature is examined to see whether or not his field observations are in keeping with the results obtained from laboratory experimentation on the respiratory function of fishes, it is found that the two do not agree. Laboratory experimentation shows that oxygen want is felt by neither fresh-water nor marine fishes until the oxygen content of the water has been reduced to about 1.7 to 0.4 cc. oxygen per liter (Duncan and Hoppe-Seyler 1893, Chlopin and Nikitin as cited by Kupzis in 1901, König and Hünneke 1901, Kupzis 1901, Winterstein 1908, Henze 1910, Gardner and Leetham 1914 and 1914a, and Gaarder 1918). Duncan and Hoppe-Seyler found that this was not only true for *Tinca vulgaris* but for *Salmo fario*, the brook trout, as well. The oxygen content of all waters observed by Roule in which salmon appeared was far in excess of the amount necessary for fishes to live without visibly showing oxygen want. Gaarder in his investigation performed very careful experiments to determine the actual oxygen consumption at different oxygen tensions. He found a very slight decrease in oxygen consumption by the carp, *Cyprinus carpio*, with a decrease in the oxygen content of the water. This decrease was very slight as compared with the lowering of the oxygen of the water.

This work favors Roule's view. But Gaarder's experiments were performed on anaesthetized fish by means of forced respiration; and in all cases more than 1 cc. oxygen per liter, and in most cases 1.5 cc., was extracted from the water when passing over the gills of the fish; further it is not known just how much a slight lowering of oxygen consumption, such as found in Gaarder's experiments, could be corrected by the variations of the respiratory movements of the fish itself. It has been shown by Baglioni (1908) and others that as the oxygen content of the water diminishes, the respiratory movements of the fish increase in rapidity and force and finally acquire a dyspnoeic character. Again, from the experiments of Gaarder one is to conclude that the oxygen consumption of a fish is never at its best in nature since the oxygen tension in natural waters never reaches that above which the oxygen consumption was not increased with a rise in tension.

Krogh and Leitch (1919) have determined the oxygen tension of unloading of the haemoglobin of the blood, i. e., the tension at which the blood is half saturated with oxygen, of the carp, eel, pike, trout, cod and plaice. They found that the oxygen tension for unloading at 15° C. and in the absence of carbon dioxide, for carp, eel, and pike, which are occasionally subjected to low oxygen tension and perhaps high carbon dioxide content of the water, was comparatively low (2 to 3 mm.). On the other hand, that of the cod was 18 mm. and of the plaice and trout 10 to 11 mm. In all, the presence of a small amount of carbon dioxide diminishes greatly the affinity of the haemoglobin for oxygen. In the carp, eel and pike, with a 1% carbon dioxide tension the unloading is increased to 7.5 mm.

When considering the results of Krogh and Leitch's observations the question is raised as to just what part the carbon dioxide tension plays in nature as affecting the unloading tension of the haemoglobin of the blood of fishes? The very fact that they found that the fishes which are subjected occasionally to lower oxygen tension and higher carbon dioxide content have a lower unloading oxygen tension than those not subjected to these conditions; and the fact that the experiments and field observations recorded in this paper show that the fishes which live on the bottom and among the vegetation did not react to a gradient of hydrogen-ion concentration, while the more freely swimming forms did so and were found always in water having a pH at or near that to which they reacted positively in the experiments, are very suggestive. Another point is, how do fishes get rid of the excess carbon dioxide in their blood? If it is through their gills it is *a priori* that the unloading of the haemoglobin would be affected by the carbon dioxide tension of the water bathing the gills of the fish. Henderson and Cohn



(1916)) and McClendon (1917) have shown that the carbon dioxide tension of sea-water with a given alkaline reserve and temperature is proportional to the pH.

The importance of the whole relation of the fish to the pH of the water, i. e., the carbon dioxide tension, is further emphasized since the fish is a rather highly organized animal as far as its physiological processes are concerned and possesses a mechanism for controlling the pH of its blood which is perhaps very delicate. Haldane and Priestley (1905), Barcroft and Roberts (1909), Barcroft and Hill (1910), Barcroft (1914) and others have shown that there is a very delicate balance of the respiratory centers of mammals in relations to the carbon dioxide of the blood. Moore, Roaf and Whitley (1906), Roaf and Whitley (1906), L. J. Henderson (1906, 1908), Henderson and Black (1907), Moore, Roaf and Knowles (1908), Sørensen (1909, 1912) and others have lead to work showing the great importance of the buffer action of the blood. Greater emphasis has been placed upon the importance of very slight variations in the relative amount of carbon dioxide in the blood by Van Slyke (1917). The cause of mountain sickness (Mosso 1898, Haldane and Priestley 1905) and shock (Y. Henderson 1908\*) only emphasize the importance of this relation. It would be surprising if one found that the general metabolism of the fish is not affected by the variation in carbon dioxide tension of the water rather than that it is. Then, again, it is interesting to note just at this point that the class of fishes which reacted most definitely to a gradient of hydrogen-ion concentration was, according to Krogh and Leitch, least adapted to withstand low oxygen tension; and the class best adapted to withstand low oxygen tension reacted less or not at all to a hydrogen-ion concentration gradient. As Krogh and Leitch have pointed out, the difference in the adaptation of the haemoglobin of the blood of these two classes of fishes to unload at low oxygen tensions could not be due to the difference in oxygen content of the sea-water, since the difference in oxygen content of the sea-water near the bottom and that above is very small if any. They suggest that the difference found in the two classes of fishes might be accounted for on the ground that the mechanical ventilation of the gills is so much hindered in a fish lying partly buried in the bottom that it becomes essential for it to utilize the oxygen down to a low tension. But might it not be explained that perhaps the carbon dioxide tension of the water at and near the bottom is higher, due to decay of organic matter, and that the fish is adapted to withstand higher carbon dioxide tension, rather

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\*For further work see *Amer. Jour. Physiol.*, 23:345-373; 24:66-85; 25:310-323, 335-402; 26:260-286; 27:153-176.

than to utilize the oxygen at a low tension? Might it not also be possible that the greater difficulty in maintaining a sea-water aquarium for fish is due not so much to the low oxygen tension as to the variation of the carbon dioxide tension of the water which causes the ill effect on the fish? The writer has had experiences in caring for live marine fishes which suggest this possibility. Works that have already been quoted show that the lowering of the relative amount of carbon dioxide in the blood of man has an ill effect, as well as raising it. The question is then raised, does the fact that the blood of certain classes of fishes is better adapted to unload the haemoglobin at low oxygen tension than that of other classes adapt them to withstand lower oxygen tension, or does it adapt them to withstand wider variations in the carbon dioxide tension, or both? If it is in any way an adaptation to withstand a wider variation in the carbon dioxide tension there is agreement between the habitat of fishes, the adaptability of the haemoglobin of their blood in unloading at specific oxygen tensions, and their behavior toward a hydrogen-ion concentration gradient.

It is not the opinion of the writer that the hydrogen-ion concentration or the carbon dioxide tension of the water is the controlling factor in the behavior of all fishes, but that there are many factors the dominance of which might vary with different species and classes of fishes, or at different seasons of the year with the same species of fish. From the foregoing observations it seems that either the hydrogen-ion concentration or the carbon dioxide tension of the water has perhaps a very large influence upon the movements of the more pelagic forms of marine fishes. Moore, Prideaux and Herdman (1915) have shown that there is a seasonal variation in the hydrogen-ion concentration (carbon dioxide tension) of the sea-water, but as far as the writer is aware nothing is known of the seasonal variation of the carbon dioxide tension of running fresh water. There might also be a seasonal variation in the rate of metabolism of the fish which would cause a variation in its behavior toward the hydrogen-ion concentration or carbon dioxide tension of the water at different seasons of the year. Hamburger and Brinkman (1918) have shown a seasonal variation in the calcium metabolism of the frog, but nothing is known of its variation in fishes (Krogh 1916). However, Meek (1916) says, "It has to be recalled, too, that the winters are recorded on the scales, that the salmon, like the fish of the north generally, suffer a relapse in physiological processes in the winter."

## E. ACKNOWLEDGMENT

The writer takes this opportunity to express his sincere thanks to Professor T. C. Frye, Director of the Puget Sound Biological Station, for many courtesies during the course of the work, and to the President and Board of Directors of the University of Washington for funds and equipment for carrying on the work. The writer, also, wishes to thank Dr. J. T. Nichols of the Department of Ichthyology, American Museum of Natural History, for the identification of certain of the fishes used in the experiments.

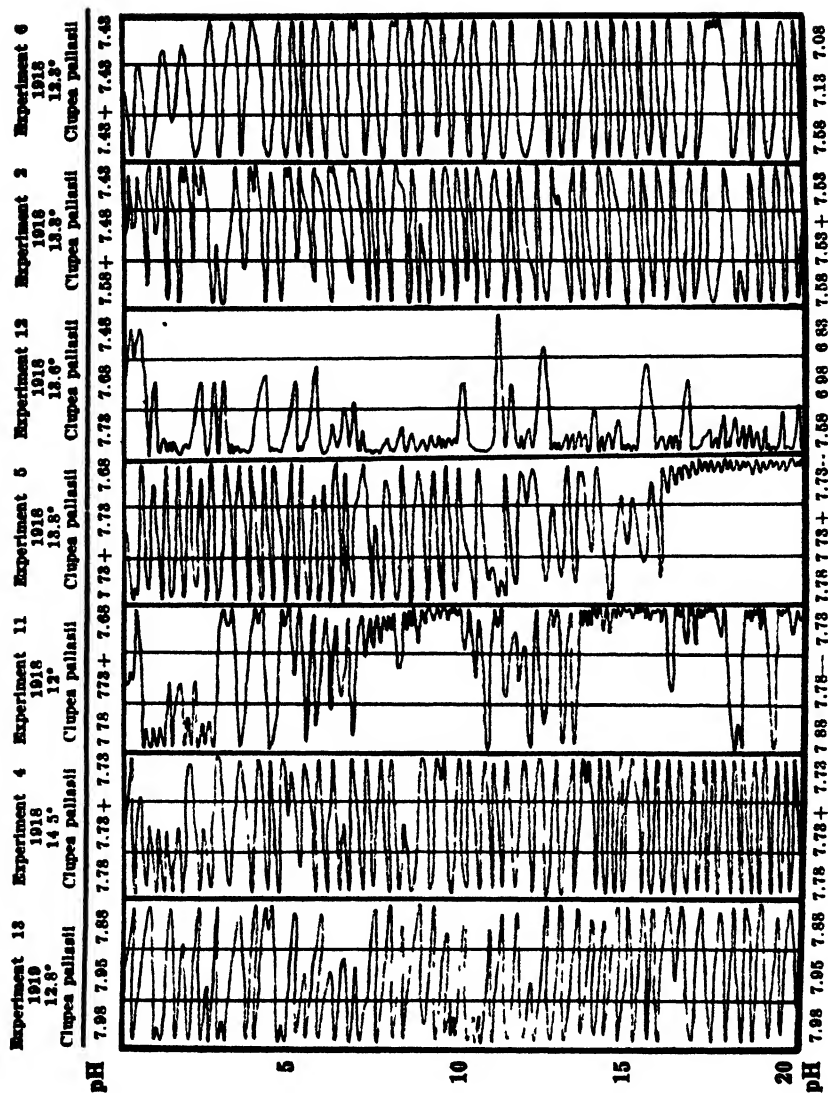


PLATE 1

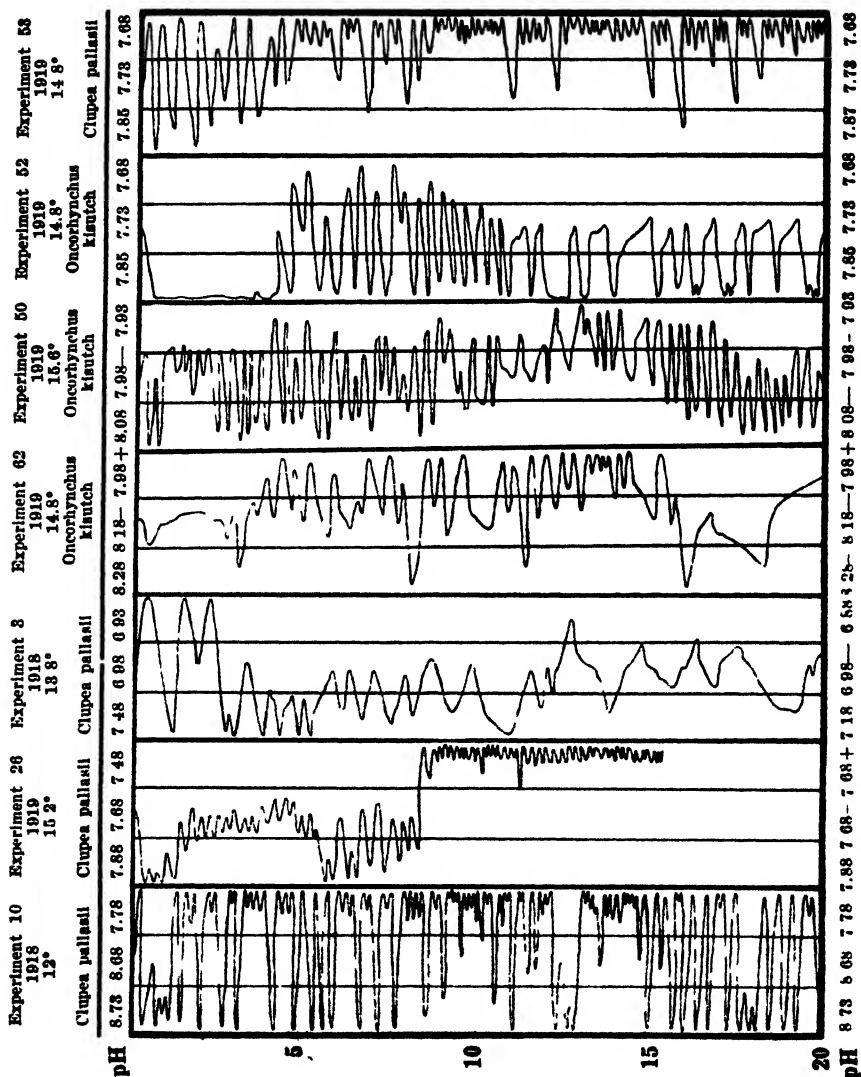


PLATE 2

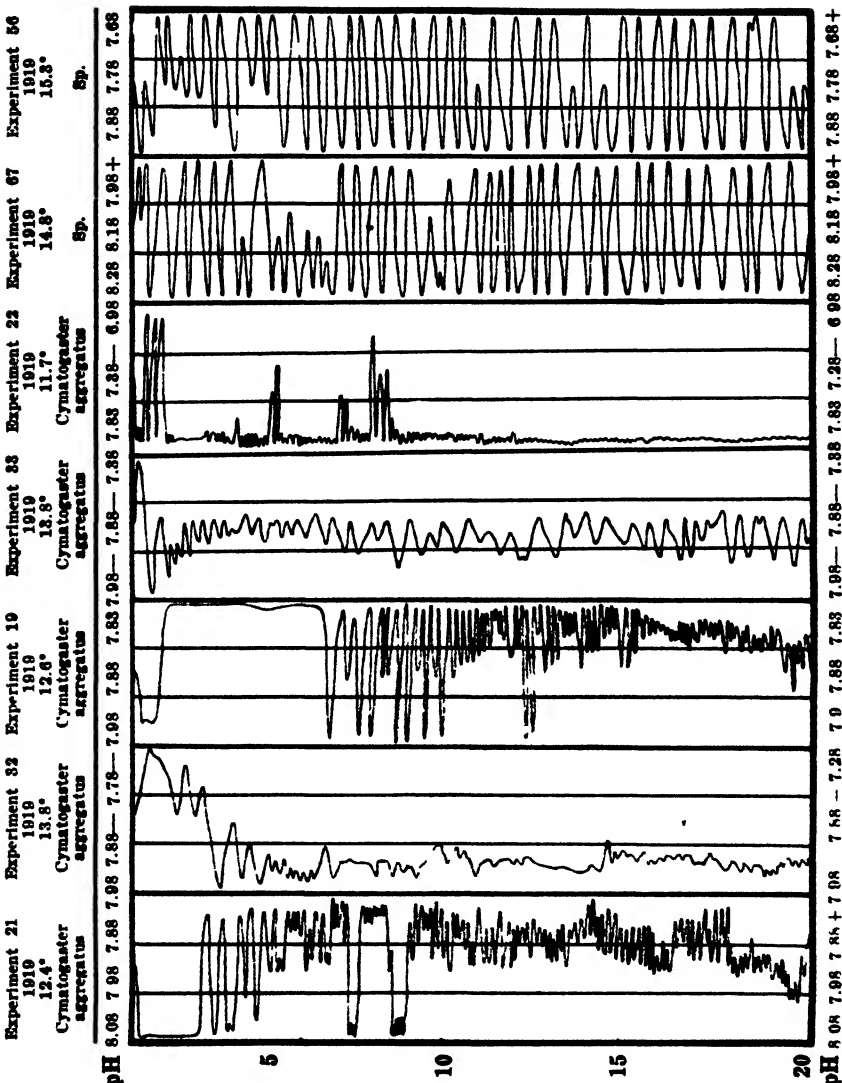


PLATE 3



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## **Mosses of the Bureau of Soils Kelp Expedition to Alaska.**

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This paper is chiefly a report on the mosses collected by the two parties comprising the United States Bureau of Soils Kelp Investigation Expedition to Alaska in 1913. All the collecting was done at odd times when through weather, accidents, or other causes it was impossible to work on the kelp survey. For that reason there was no choice of locality; all mosses were gathered comparatively near the seashore, and often in the least promising regions from the collector's standpoint. About 1000 packages were gathered, many of which were taken as a record for distribution and abundance. No attempt was made to find everything in any region. The moss, lichen and liverwort packages of the expedition were numbered successively. The numbers are therefore not those of the collectors, but those of the expedition.

Two mutually independent parties comprised the expedition. That to southwestern Alaska, in charge of Dr. G. B. Rigg of the University of Washington, was further composed of Dr. Robert Griggs of the University of Ohio and Mr. S. M. Zeller of the University of Washington. Its collections were made from Yakutat to the Shumagin Islands, and mostly by Dr. Rigg. The number of moss packages was roughly 100.

The party to southeastern Alaska, in charge of Dr. T. C. Frye of the University of Washington, was further composed of Dr. R. B. Wylie of the University of Iowa and Mr. Dean Waynick of the University of Washington. During 6 weeks' absence by Dr. Wylie, Mr. A. S. Foster filled his place. About 900 packages were collected, mostly by Dr. Frye. All were gathered south of a line drawn east and west through Juneau.

The parties left Seattle, Washington, May 1, and returned not later than Sept. 15. That under Dr. Frye had three opportunities for

collecting plants on the way to Alaska, by utilizing evenings; at Shell Island, Swanson Bay and Lewis Island. These are included, as are mosses sent to the University of Washington, from Alaska and Yukon at various times. When no name is mentioned the collector was a member of the expedition; all others are expressly mentioned. They are the following:

C. H. Townsend, about whom we know nothing. Kodiak, 1888.

Emma A. Shumway, teacher Seattle high schools. Juneau and vicinity, 1891.

Trevor Kincaid, professor of zoology in the University of Washington. Shumagin Islands and the seal islands in Bering Sea, 1898 and 1899.

George Henwick, about whom we know nothing. Dawson, Yukon, 1900.

Albert Mehner, teacher Juneau high school. Juneau and vicinity, 1904 and 1905.

Mrs. Ella Engstrom, now Mrs. F. W. Kirsten of Everett, Washington. Wrangell, 1904 and 1905.

Lois Clark, teacher high school, Douglas, Alaska. Douglas and vicinity, 1908.

D. S. Birkett, geological student in the University of Washington. Prince William Sound, 1907.

Orah Dee Clark, teacher Indian schools. Tanana, Skagway and Ketchikan, and also at Dawson, Yukon, 1910 and 1911.

Ruth Mylroie, teacher Indian schools. Kodiak, 1910 and 1911.

A. S. Foster, teacher in the public schools of the state of Washington, after severing his connection with the expedition, collected some at Wrangell, and also at Prince Rupert, B. C. 1913.

Grace A. Hill, teacher Indian schools. Sinuk, 1915.

Below are given most of the localities mentioned in the paper, with approximate latitude and longitude.

Aats Bay, Lat.  $55^{\circ} 55'$ , Long.  $134^{\circ} 20'$ ; northwestern shore of Coronation Island. Agattu Island, Lat.  $52^{\circ} 0'$ , Long.  $173^{\circ} 0'$  E.; the extreme island of the Aleution chain. Alimvoak Bay, Lat.  $58^{\circ} 10'$ , Long.  $153^{\circ} 0'$ ; southwestern shore of Afognak Island. Augustine Bay, Lat.  $55^{\circ} 0'$ , Long.  $133^{\circ} 13'$ ; first indentation north of Cape Augustine.

Baranof, Lat.  $57^{\circ} 5'$ , Long.  $134^{\circ} 50'$ ; post office and warm spring, on Warm Spring Bay. Brownson Bay, Lat.  $54^{\circ} 45'$ , Long.  $132^{\circ} 14'$ .

Caldër, Lat.  $56^{\circ} 10'$ , Long.  $133^{\circ} 28'$ ; marble quarry and formerly a post office. Cape Alitka, Lat.  $56^{\circ} 52'$ , Long.  $154^{\circ} 18'$ . Cape Douglas, Lat.  $58^{\circ} 55'$ , Long.  $153^{\circ} 20'$ ; west side of the entrance to Cook

Inlet. Cape Fox, Lat.  $54^{\circ} 42'$ , Long.  $130^{\circ} 50'$ . Cape Nome, Lat.  $64^{\circ} 50'$ , Long.  $164^{\circ} 55'$ . Cape Prince of Wales, Lat.  $65^{\circ} 38'$ , Long.  $168^{\circ} 3'$ . Chinitna Bay, Lat.  $59^{\circ} 50'$ , Long.  $153^{\circ} 0'$ ; west shore of Cook Inlet. Coal Harbor, Lat.  $55^{\circ} 20'$ , Long.  $160^{\circ} 40'$ ; northern shore of Unga Island in the Shumagin group. Controller Bay, Lat.  $60^{\circ} 5'$ , Long.  $144^{\circ} 8'$ . Cordova, Lat.  $60^{\circ} 50'$ , Long.  $145^{\circ} 40'$ .

Dawson, Yukon, Lat.  $64^{\circ} 5'$ , Long.  $139^{\circ} 25'$ . Deweyville, Lat.  $55^{\circ} 48'$ , Long.  $133^{\circ} 15'$ ; an Indian village. Douglas, Lat.  $58^{\circ} 16'$ , Long.  $134^{\circ} 29'$ . Douglas Island, Lat.  $58^{\circ} 16'$ , Long.  $134^{\circ} 30'$ .

Egg Harbor, Lat.  $55^{\circ} 55'$ , Long.  $134^{\circ} 20'$ ; northwestern shore of Coronation Island. Exchange Cove, Lat.  $56^{\circ} 11'$ , Long.  $133^{\circ} 5'$ .

Farragut Bay, Lat.  $57^{\circ} 7'$ , Long.  $133^{\circ} 14'$ .

Gladhaugh Bay, formerly Virgin Bay, Lat.  $61^{\circ} 4'$ , Long.  $146^{\circ} 19'$ . Grewingk Glacier, Lat.  $59^{\circ} 38'$ , Long.  $151^{\circ} 5'$ .

Hall Island, Lat.  $60^{\circ} 35'$ , Long.  $172^{\circ} 35'$ . Hidden Inlet, Lat.  $54^{\circ} 56'$ , Long.  $130^{\circ} 20'$ . Hoodoo Islands, Lat. and Long. not known to us; southwestern part of Prince William Sound; sometimes known as the Flemming group. Hunts Cannery, Lat.  $56^{\circ} 19'$ , Long.  $134^{\circ} 1'$ ; west shore of Port Beauclerc.

Izhut Bay, Lat.  $58^{\circ} 22'$ , Long.  $152^{\circ} 12'$ ; southeastern shore of Afognak Island.

Juneau, Lat.  $58^{\circ} 18'$ , Long.  $134^{\circ} 25'$ .

Kanaganut Island, Lat.  $54^{\circ} 45'$ , Long.  $130^{\circ} 43'$ . Ketchikan, Lat.  $55^{\circ} 20'$ , Long.  $131^{\circ} 39'$ . Kodiak, Lat.  $57^{\circ} 46'$ , Long.  $152^{\circ} 25'$ ; village. Kvichak River, Lat.  $59^{\circ} 8'$ , Long.  $156^{\circ} 40'$ ; at western base of Alaska Peninsula.

Lake Bay, Lat.  $56^{\circ} 1'$ , Long.  $132^{\circ} 55'$ . La Touche Island, Lat.  $60^{\circ} 0'$ , Long.  $147^{\circ} 50'$ . Lazy Bay, Lat.  $56^{\circ} 52'$ , Long.  $154^{\circ} 8'$ ; southwestern shore of Kodiak Island, about 4 miles inside Cape Alitka. Lewis Island, B. C., Lat.  $54^{\circ} 4'$ , Long.  $130^{\circ} 15'$ . Lituya Bay, Lat.  $58^{\circ} 37'$ , Long.  $137^{\circ} 32'$ . Lynn Canal, Lat.  $58^{\circ} 45'$ , Long.  $135^{\circ} 15'$ .

Metlakatla, Lat.  $55^{\circ} 8'$ , Long.  $131^{\circ} 55'$ ; an Indian village. Mitrofan Bay, Lat.  $56^{\circ} 0'$ , Long.  $158^{\circ} 50'$ . Morse Cove, Lat.  $54^{\circ} 55'$ , Long.  $131^{\circ} 17'$ ; eastern shore of Duke Island. Mt. Fairweather, Lat.  $58^{\circ} 55'$ , Long.  $137^{\circ} 32'$ .

Nichols Bay, Lat.  $54^{\circ} 43'$ , Long.  $132^{\circ} 8'$ . Northwest Harbor,  $54^{\circ} 55'$ , Long.  $159^{\circ} 20'$ ; north shore of Little Koniuji Island.

Orca, Lat.  $60^{\circ} 35'$ , Long.  $145^{\circ} 45'$ .

Popoff Island, Lat.  $55^{\circ} 20'$ , Long.  $160^{\circ} 30'$ ; one of the Shumagin group. Port Alice, Lat.  $55^{\circ} 48'$ , Long.  $133^{\circ} 24'$ . Port Chatham, Lat.  $59^{\circ} 10'$ , Long.  $151^{\circ} 40'$ . Port Clarence, Lat.  $65^{\circ} 8'$ , Long.  $166^{\circ} 40'$ .

Port Etches, Lat.  $60^{\circ} 20'$ , Long.  $146^{\circ} 35'$ . Port Malmsbury, Lat.  $56^{\circ} 17'$ , Long.  $134^{\circ} 9'$ . Port San Antonio, Lat.  $55^{\circ} 21'$ , Long.  $133^{\circ} 37'$ . Prince Rupert, B. C., Lat.  $54^{\circ} 10'$ , Long.  $130^{\circ} 0'$ .

Ratz Harbor, Lat.  $55^{\circ} 53'$ , Long.  $132^{\circ} 36'$ .

St. George Island, Lat.  $56^{\circ} 35'$ , Long.  $169^{\circ} 40'$ . St. John Harbor Lat.  $56^{\circ} 26'$ , Long.  $132^{\circ} 57'$ . St. Michael, Lat.  $63^{\circ} 38'$ , Long.  $162^{\circ} 26'$ . St. Paul Island, Lat.  $57^{\circ} 10'$ , Long.  $170^{\circ} 5'$ . Saltery Cove, Lat.  $55^{\circ} 24'$ , Long.  $132^{\circ} 19'$ . Seldovia, Lat.  $59^{\circ} 20'$ , Long.  $151^{\circ} 32'$ . Seward, Lat.  $60^{\circ} 6'$ , Long.  $149^{\circ} 20'$ . Shell Island, B. C., Lat.  $50^{\circ} 43'$ , Long.  $127^{\circ} 25'$ . Shipley Bay, Lat.  $56^{\circ} 5'$ , Long.  $133^{\circ} 30'$ . Shuyak Island, Lat.  $58^{\circ} 35'$ , Long.  $152^{\circ} 55'$ . Sinuk, Lat.  $64^{\circ} 35'$ , Long.  $166^{\circ} 20'$ . Sitka, Lat.  $57^{\circ} 5'$ , Long.  $135^{\circ} 15'$ . Sitklan Island, Lat.  $54^{\circ} 45'$ , Long.  $130^{\circ} 42'$ . Skagway, Lat.  $57^{\circ} 31'$ , Long.  $135^{\circ} 15'$ . Snug Harbor, Lat.  $56^{\circ} 50'$ , Long.  $154^{\circ} 0'$ . Stepovak Bay, Lat.  $55^{\circ} 45'$ , Long.  $159^{\circ} 45'$ . Swanson Bay, B. C., Lat.  $53^{\circ} 1'$ , Long.  $128^{\circ} 31'$ . Swifts Cannery, Lat.  $55^{\circ} 40'$ , Long.  $133^{\circ} 30'$ ; on the west shore of the largest indentation on the south side of Heceta Island.

Tam Gas Harbor, Lat.  $55^{\circ} 4'$ , Long.  $131^{\circ} 33'$ . Tanana, Lat.  $65^{\circ} 15'$ , Long.  $152^{\circ} 0'$ ; town near the mouth of the Tanana River. Three Saints Bay, Lat.  $57^{\circ} 15'$ , Long.  $153^{\circ} 0'$ . Tongass Island, Lat.  $54^{\circ} 48'$ , Long.  $130^{\circ} 44'$ . Turner River, Lat.  $58^{\circ} 19'$ , Long.  $133^{\circ} 58'$ ; the outlet of Turner Lake.

Unalaska, Lat.  $53^{\circ} 40'$ , Long.  $166^{\circ} 35'$ . Unimak Pass, Lat.  $54^{\circ} 15'$ , Long.  $165^{\circ} 0'$ . Uzinki, Lat.  $57^{\circ} 55'$ , Long.  $153^{\circ} 0'$ ; village on Spruce Island.

Verdure Creek, Lat.  $55^{\circ} 45'$ , Long.  $130^{\circ} 10'$ ; flowing into the north side of Portland Canal, perhaps 10 miles below its head. Virgin Bay, now Gladhaugh Bay.

Woewodski Island, Lat.  $56^{\circ} 32'$ , Long.  $133^{\circ} 2'$ . Wrangell, Lat.  $56^{\circ} 28'$ , Long.  $132^{\circ} 22'$ .

Yakutat, Lat.  $59^{\circ} 40'$ , Long.  $139^{\circ} 40'$ .

The extreme width of Alaska, including its islands, is over 4000 Km. (2500 miles), and the extreme length north and south is over 2250 Km. (1400 miles). The range of species within the territory is therefore given, but no attempt is made to indicate the range outside. For the sake of brevity the following abbreviations are used in indicating range:

N, (north), the shore region from Cape Prince of Wales northward and eastward.

B, (Bering), the islands of Bering Sea, and a 10-mile strip of shore from Cape Prince of Wales southeastward to the Kvichak River, at the base of the Alaska Peninsula.

T., (Tanana), the whole interior of Alaska not included in the other areas. We know of no collections from the interior except from the Yukon River valley.

A, (Aleutian), the Aleutian Islands to Unimak Pass.

P, (peninsula), The Alaska Peninsula and adjacent islands.

S, (Seward), the whole coastal region from Cook Inlet to Controller Bay.

Y, (Yakutat), Yakutat Bay and vicinity.

J, (Juneau), the whole of southeastern Alaska included within the boundaries southeastward from Mt. Fairweather and Lituya Bay.

#### SPHAGNACEAE\*

*Sphagnum angstroemii* Hartm. St. Paul Island (Kincaid in 1899); Wrangell (1344).—Range, B. J.

Its Alaskan range was limited to Hall Island in Bering Sea (Trelease, 1910), although it was known from Yukon (Andrews, 1913). Its occurrence in southeastern Alaska was unexpected.

*Sphagnum capillaceum tenellum* (Schimp.) Andrews, in New York Botanical Garden's "North American Flora" 15: 28. 1913. (*S. rubellum* Wils.; *S. rubellum violascens* Warnst.) Metlakatla (99); Morse Cove (432); Three Saints Bay (1284); Snug Harbor (1289); Tanana (O. Clark in 1911); Wrangell (1190, 1193).—Range, B. A. S. J.

*Sphagnum compactum* DC. (*S. compactum imbricatum* Warnst.) Mitrofan Bay (1288).—Range, A. P. J.

*Sphagnum fuscum* (Schimp.) H. Klinggr. (*S. fuscum pallescens* Warnst.; *S. fuscum robustum* Warnst.) Metlakatla (95).—Range, B. P. S. J.

*Sphagnum girgensohnii* Russ. (*S. girgensohnii xerophilum* Russ.) Aats Bay (929); Augustine Bay (548); Calder (846); Cordova (Birkett in 1907); Exchange Cove (265); Juneau (Mehner in 1904); Lake Bay (195); Morse Cove (437); Northwest Harbor (1281); Orca (Birkett in 1907); Port Chatham (1280); St. John Harbor (225); St. Paul Island (Kincaid in 1899); Sinuk (Hill in 1915); Snug Harbor (1282); Swanson Bay, B. C. (1292); Swifts Cannery (687); Tam Gas Harbor (147); Tanana (O. Clark in 1911); Three Saints Bay (1283); Verdure Creek (32); Yakutat Bay (1279).—Range, T. B. A. P. S. Y. J.

This is apparently one of the most common species of this genus in Alaska.

\*The ranges of the species of *Sphagnum* are not very accurate. The excessive splitting of species previous to Andrews' (1913) excellent work in the New York Botanical Garden's "North American Flora" makes it hard to tell exactly what collectors gathered, from their reports.



*Sphagnum lindbergii* Schimp. (*S. lindbergii immersum* Limpr.; *S. lindbergii microphyllum* Warnst.; *S. lindbergii macrophyllum fluitans* Warnst.; *S. lindbergii mesophyllum* Warnst.) Juneau (Mehner in 1905).—Range, B. J.

*Sphagnum magellanicum* Brid. (*S. medium* Limpr.; *S. medium pallescens* Warnst.; *S. medium obscurum brachycladum* Warnst.; *S. subbicolor flavescens* Warnst.) Port San Antonio (598, 1191); Three Saints Bay (1290); Wrangell (1194); Yakutat (1291).—Range, B. A. S. Y. J.

*Sphagnum palustre* L. (*S. cymbifolium* Ehrh.) Port Alice (791).—Range, A. J.

*Sphagnum papillosum* Lindb. (*S. papillosum normale* Warnst.) Metlakatla (108); Nichols Bay (390).—Range, P. S. J.

*Sphagnum quinquefarinum* (Lindb.) Warnst. Juneau (Mehner in 1904). This is the first report of its occurrence in Alaska, although it is found in eastern North America.

*Sphagnum robustum* (Russ.) Roell. (*S. russowii* Warnst.; *S. russowii rhodochroum* Russ.) Juneau (Mehner in 1904).—Range, S. J. S. J.

*Sphagnum squarrosum* Crome. (*S. squarrosum imbricatum* Schimp.; *S. squarrosum subsquarrosum* Warnst.; *S. squarrosum semisquarrosum* Russ.) St. Paul Island (Kincaid in 1899); Turner River (1031).—Range, B. A. P. S. Y. J.

*Sphagnum tenellum* Pers. (*S. molluscum* Bruch). Baranof (1074); Lazy Bay (1287); Mitrofanina Bay (1285); Port Malmsbury (981); Port San Antonio (597); St. George Island (Kincaid in 1899); Salt-ery Cove (334).—Range, B. P. S. J.

This was known to occur in Alaska only at Gladhaugh Bay (Virgin Bay) on Prince William Sound (Trelease, 1910). Apparently it is not uncommon, and is wide in its distribution.

*Sphagnum teres* (Schimp.) Angstr. (*S. teres squarrosulum* Schimp.; *S. teres imbricatum* Warnst.) Kodiak (Mylroie in 1911); Stepovak Bay (1286).—Range, T. B. A. P. J.

*Sphagnum warnstorffii* Russ. (*S. warnstorffii purpurascens* Russ.; *S. warnstorffii violascens* Warnst.; *S. warnstorffii flavescens* Russ.) Tanana (O. Clark in 1910).—Range, P. S.

#### ANDREAEACEAE

*Andreaea petrophila* Ehrh. (*A. petrophila sylvicola* B. S. G.; *A. petrophila acuminata* Schimp.) Brownson Bay (490); Metlakatla (107); Nichols Bay (367, 371).—Range, B. S. J.

*Andreaea alpestris* (Thed.) Schimp. (*A. parvifolia* C. Muell.; *A. petrophila parvifolia* Wms.) Mitrofan Bay, altitude 460 meters (1314).—Range, P. J.

There is no definite report known to us of its previous collection in Alaska except in the southeastern portion; although Flora, p. 219, 1887, is not available to us. This is therefore a considerable extension of its range westward.

#### DITRICHACEAE

*Swartzia montana* (Lam.) Lindb. (*Distichium capillaceum* B. S. G.) Brownson Bay (478); Egg Harbor (854); St. Paul Island (Kincaid in 1899); Seward (1295, 1296); Tanana (O. Clark in 1910).—Range, N. T. B. A. S. Y. J.

*Ceratodon purpureus* (L.) Brid. (*C. heterophyllus* Lindb.) Baranof (1076); Calder (823, 832); Grenwingk Glacier (1299); Juneau (Mehner in 1904 and 1905); Ketchikan (431, 516, O. Clark in 1910); Kodiak (Mylroie in 1910 and 1911); Mitrofan Bay (1297, 1298); St. Paul Island (Kincaid in 1899); Shell Island, B. C. (1199, 1202); Tanana (O. Clark in 1910 and 1911); Woewodski Island (967).—Range, N. T. B. A. P. S. Y. J.

*Ditrichum heteromallum* (Hedw.) E. G. Brit. (*D. homomallum* Hampe). Dawson, Yukon Territory (O. Clark in 1910).—Range, P.

This is known only from Kodiak in its Alaskan distribution (Cardot and Theriot, 1910); but its occurrence at Dawson makes a wide distribution in Alaska probable.

#### SELIGERiaceae

*Blindia acuta* (Huds.) B. S. G. (*B. acuta flexipes* R. & C.) Juneau (Shumway in 1891); Port Chatham (1293, 1294, 1308 in part).—Range, B. A. S. J.

#### DICRANACEAE

*Dicranella grevilleana* (Brid.) Schimp. Calder (824).—Range, B. J.

This was known from Alaska only from Port Clarence and St. Michael, both in the northern portion of the Bering Sea.

*Dicranella heteromalla* (L.) Schimp. (*D. heteromalla orthophylla* Lesq. & James; *D. heterophylla latincervis* Card. & Ther.; *Dicranum heteromallum* Hedw.) Augustine Bay (559); Baranof (1075); Juneau (Shumway in 1891); Port San Antonio (596).—Range, P. J.

*Dicranella squarrosa* (Schrud.) Schimp. Mitrofan Bay, altitude 455 meters (1314 in part).—Range, P.

While this has been reported from Alaska before, all the reports available to us give the location merely as "Alaska" (John Macoun, 1892; Cardot & Theriot, 1892-93; Merriam, 1892).

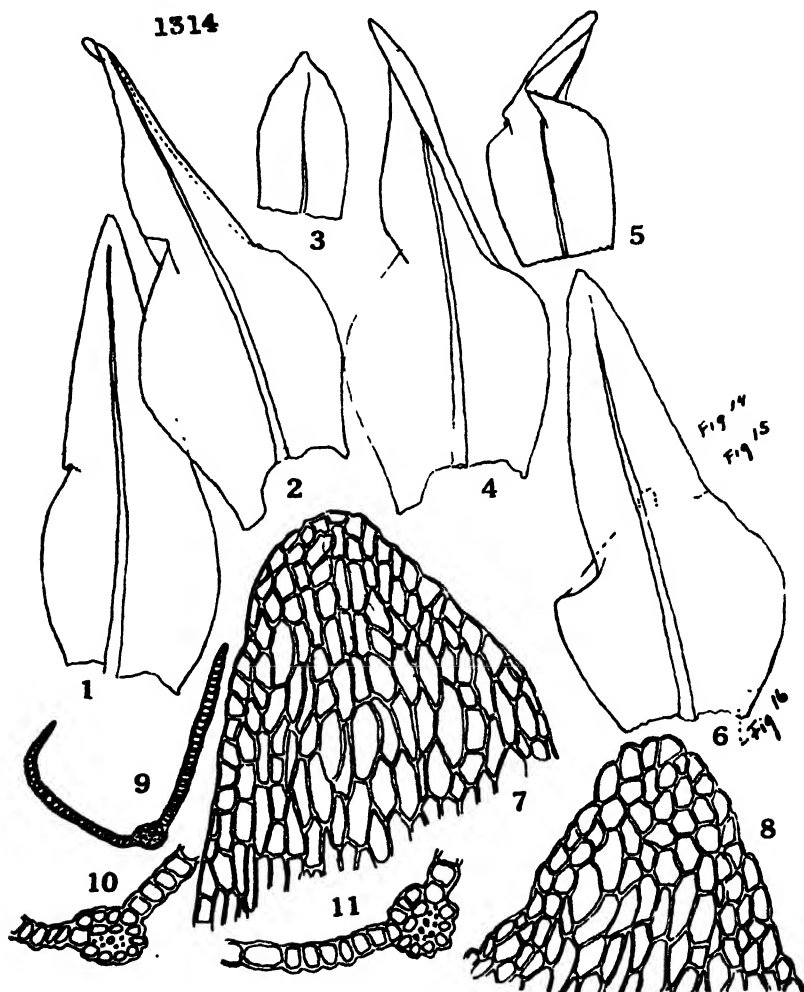
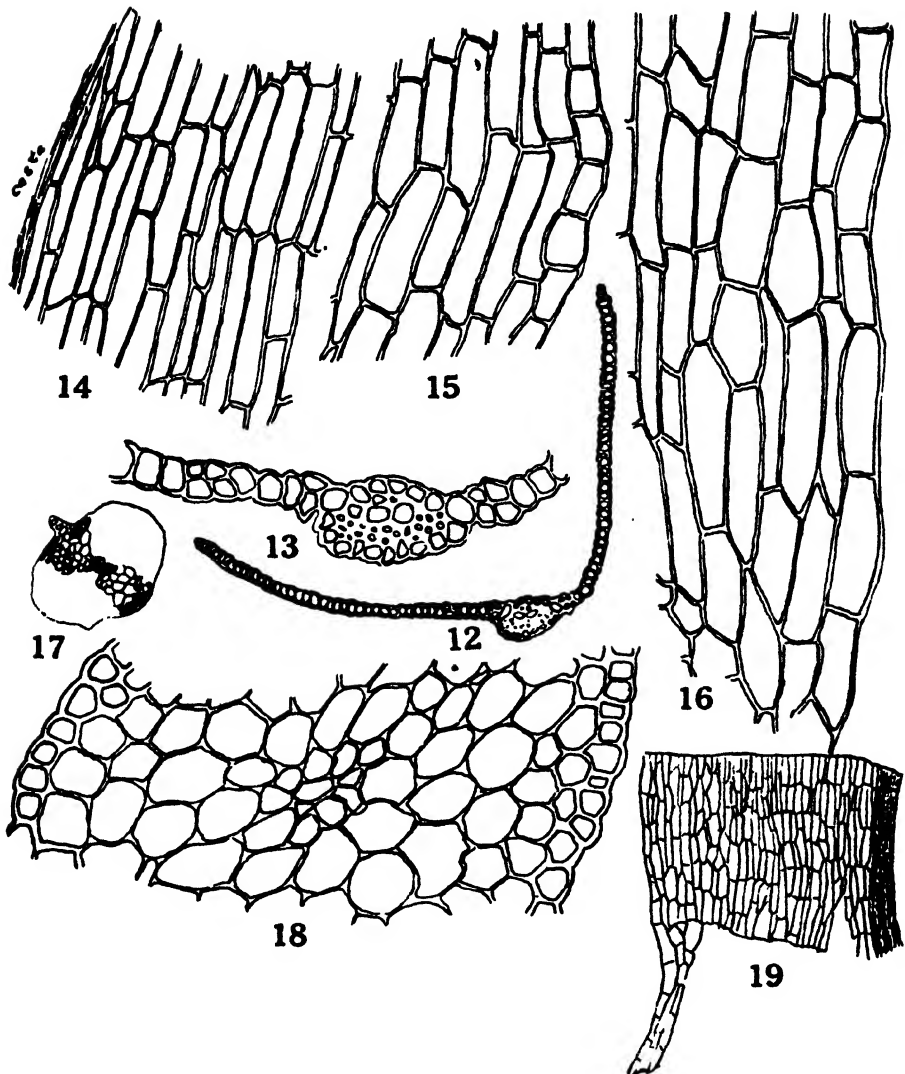


PLATE 5

*Diceranella squarrosa*, drawn from No. 1314.

Figs. 1, 2, 4, 6. Leaves from median to upper portion of stem;  $\times 22$ .  
 Fig. 3. Leaf from lower part of stem;  $\times 22$ . Fig. 5. Leaf from young stem;  
 $\times 22$ . Fig. 7. Apex of leaf of Fig. 1;  $\times 217$ . Fig. 8. Apex of leaf of Fig. 6;  
 $\times 217$ . Fig. 9. Median cross section of mature median leaf;  $\times 87$ . Fig. 10.  
 Costa of Fig. 9;  $\times 217$ . Fig. 11. Costa of section nearer apex than Fig. 10;  $\times 217$ .



## PLATE 6

*Dicranella squarrosa*, drawn from No. 1314

*Fig. 12.* Basal section of well developed leaf  $\times 87$  *Fig. 13* Costa of section in *Fig. 12*;  $\times 217$ . *Fig. 14.* Areolation of leaf on *Fig. 6*, at medium costa (as marked);  $\times 217$ . *Fig. 15.* Areolation of leaf in *Fig. 6*, at median margin (as marked);  $\times 217$ . *Fig. 16.* Areolation of leaf in *Fig. 6*, at basal angle (as marked);  $\times 217$ . *Fig. 17.* Cross section of well developed stem;  $\times 87$ . *Fig. 18.* Portion of *Fig. 17*, enlarged;  $\times 217$ . *Fig. 19.* Leaf base of mature leaf;  $\times 87$ .

*Dicranoweisia crispula nigrescens* Nees & Hornsch. in Bryol. germ. p. 67, pl. 30, figs. 15, 16. Juneau (Shumway in 1891).

This is the only report of this variety, at least, from Alaska. The typical species has a range, B. A. J. Bruch, Schimper & Guembel, in Bryol. Eur., Suppl. I, Hymenostomum, p. 10, recognize this variety. It is also given in Schimp. Syn. (1860), p. 56. Limpricht, however, in Laubmoose, I, p. 265, speaks lightly of it, declaring it to be hardly a form. This Alaskan plant seems to justify its treatment as a variety. (Holzinger).

*Dicranoweisia contermina* Ren. & Card. Augustine Bay (672); Mitrofanina Bay, altitude 460 meters (1307).—Range, P. J.

Williams (1901) found it in southern Yukon, and later (1913) records its distribution as "Alaska to California", etc., probably from the southern Yukon material. This seems to be the first report from Alaska.

*Oncophorus virens* (Swartz) Brid. (*O. virens serratus* Limpr.; *O. virens nigrescens* Wms.; *Cynodontium virens* Schimp.; *Cynodontium virens serratum* Schimp.) Sinuk (Hill in 1915).—Range, B. S. Y.

*Oncophorus wahlenbergii* Brid. (*Cynodontium wahlenbergii* Hartm.) Sinuk (Hill in 1915).—Range, B. S.

*Dicranum bonjeanum* De-Not. (*D. dipteroneuron* C. Muell.; *D. palustre* var. of Turner, 1886). Baranof (1907); Juneau (Mehner in 1904); Kodiak (Myloie in 1911); Tanana (O. Clark in 1911).—Range, N. T. P. J.

*Dicranum elongatum* Schleich. (*D. subflagellare* Card. & Ther.) Three Saints Bay (1327, 1328).—Range, N. B. P. Y.

*Dicranum fulvellum* (Dicks.) Smith. St. George Island (Kincaid in 1899). This is the first report of this species from Alaska, although Williams (1901) found it in southern Yukon.

*Dicranum fuscescens* Turn. (*D. congestum* Brid.) Augustine Bay (567); Juneau (Shumway in 1891); Lake Bay (206); Lewis Island, B. C. (1201); Morse Cove (433); Nichols Bay (372); Port Chatham (1300); Port San Antonio (619); Shipley Bay (777); Tam Gas Harbor (116, 151, 133).—Range, P. S. Y. J.

Not uncommon in southeastern Alaska.

*Dicranum fuscescens falcifolium* Braithw., ex. char., in Brit. Moss Flora, p. 153. Cape Douglas (1333). This variety has not been reported before from Alaska.

*Dicranum groenlandicum* Brid. (Mitrofanina Bay (1320); Three Saints Bay (1306, 1312).—Range, T. B. P.

*Dicranum hyperboreum* (Gunn.) Smith. Ketchikan (499, 503); Port San Antonio (596); Sitklan Island (54); Swanson Bay, B. C.

(1200). While this is an Arctic species in eastern North America and Europe, it was known from the west coast only from Mt. Hood. Its occurrence in both B. C. and Alaska, in all cases at nearly sea level, is rather unexpected.

*Dicranum majus* Smith. (*D. majus orthophyllum* A. Br.; *D. howellii* Ren. & Card.; *D. howellii angustifolium* Kindb.) Aats Bay (902, 930); Augustine Bay (549); Egg Harbor (852); Exchange Cove (262); Juneau (Shumway in 1891); Lake Bay (194); Morse Cove (463); Northwest Harbor (1301); Port Alice (790); Port Malmsbury (979); Port San Antonio (646).—Range, P. S. Y. J.

Fairly common in southeastern Alaska in shaded damp hollows. It is a conspicuous species, which partly accounts for its frequent collection.

*Dicranum rugosum* (Hoffm.) Brid. (Not *D. rugosum* Kindb., which is *D. bergeri*). Wrangell (1203). This is the first report of this species from Alaska. It is known to occur in the coastal region of B. C. and Oregon.

*Dicranum schistii* (Gunn.) Lindb. (*D. blytii* B. S. G.; *Cynodontium treleasei* Card. & Ther.) Mitrofanía Bay, altitude 460 meters (1326).—Range, P. S.

*Dicranum scoparium* (L.) Hedw. (*D. angustifolium* Kindb.) Baranof (1079); Juneau (Shumway in 1891); Kodiak (Mylorie in 1910); Port Chatham (1302, 1304); Snug Harbor (1303); Swifts Cannery (722).—Range, N. B. A. P. S. J.

*Dicranum strictum* Schleich. Sinuk (Hill in 1915).—Range, B. A. Y.

*Campylopus schimperi* Milde. Augustine Bay (681, 682).—Range, B. J.

The only Alaskan point from which this was known is St. Paul Island (J. M. Macoun, 1899; John Macoun, 1902).

*Oreoweisia obtusata* Kindb. in Rev. bryol. 1896, p. 18. Mitrofanía Bay (1319 in part). New to Alaska. Known from the rocky mountains of British Columbia.

This moss was intermingled with a sterile *Bryum*. It suggested *Dichodontium olympicum* Ren. & Card. In areolation and leaf margin it favors *Oreoweisia serrulata* (Funck) De-Not.; but the leaves are shorter, mostly obtuse, and channeled above. Kindberg, in European and North American Bryineae (1897), p. 184, records it as *Cynodontium obtusatum* Kindb., section *Oreoweisia*. The Catalog of Canadian Plants, Part 6, Musci (1892), p. 15, gives it as *Oreoweisia serrulata tenuior* Kindb., without description. So this name becomes a *numen nudum*. Therefore Paris' Index (p. 315) is wrong in giving it as *Oreo-*

*weisia serrulata tenuior* Kindb. The first valid description is published in 1896, in *Revue bryologique*, page 18, as cited above. It seems a good species. (Holzinger).

*Dichodontium pellucidum* (L.) Schimp. (*D. pellucidum fagimontanum* Schimp.; *D. pellucidum kodiakanum* Card. & Ther.; *D. flavescens* Lindb.) Calder (862, 1195); Juneau (Mehner in 1904); Port Alice (723); St. Paul Island (Kincaid in 1899).—Range, B. A. P. S. Y. J.

#### FISSIDENTACEAE

*Fissidens grandifrons* Brid. Augustine Bay (541, 797). This seems to be the first report of any of the Fissidentaceae from Alaska. *F. adiantioides* Hedw. and *F. osmundoides* Hedw. were both found in southern Yukon by Williams (1901) and may be expected in Alaska. *F. bryoides* Hedw. is known from the Dawson region of Yukon (Williams, 1901) and may be looked for in almost any general region of Alaska.

#### TORTULACEAE

*Tortella tortuosa* (L.) Limpr. Augustine Bay (678, 682, 1184, 2462); Egg Harbor (859); Nichols Bay (377); St. John Harbor (249). This is new to Alaska, although it occurs in southern British Columbia (John Macoun, 1892). No. 678 is an unusually long-leaved form.

*Didymodon rigidulus* Hedw. Juneau (Mehner in 1904). New to Alaska. Known to occur in southern British Columbia.

*Didymodon rubellus* (Hoffm.) B. S. G. Egg Harbor (857); Skagway (O. Clark in 1910).—Range, B. A. J.

*Geheebia gigantea* (Funck) Boulay *Musc. de la France* p. 395. 1884. (*Barbula gigantea* Funck *Mscr. Flora*, 1882; *Didymodon giganteus* Jur., according to Limpr. *Laubm.*, I, p. 560; *Geheebia cataractarum* Schimp. in *Syn*, 2 ed., p. 233, 1876.\*) Aats Bay, on boulders (931). New to North America.

Schimper (*loc. cit.*) pronounces this a "genus incertae sedis". Limpricht, following Juratzka, calls it *Didymodon giganteus* (Funck) Jur. in *zool.-bot. Vehr.* 1871, and in *Laubmoos fl.* p. 102. 1882. But he frankly declares at the end of his accurate description, bottom of p. 561, that "In the anatomical structure of stem and costa it resembles *Barbula recurvifolia*, and might be placed next to this species." The generous aid of Mr. R. S. Williams is acknowledged in its determination. There seems to be no ground for denying generic rank to this

\*Two errors were discovered in this page reference: Limpricht, I, p. 560 has "p. 102"; Paris Index has "p. 228". Both need correction to p. 233

plant. By retaining Schimper's name *Geheebia* we rightly honor the judgment of one great bryologist and perpetuate the memory of another as worthy. (Holzinger).

*Pottia heimii beringianam* Card. & Ther. in Proc. Wash. Acad. Sci. 4:31, pl. 14, figs. 2a-2i, 1902. St. Paul Island (Kincaid in 1899).—Range, B.

*Tortula ruralis* (L.) Ehrh. (*Barbula ruralis* Hedw.) St. Paul Island (Kincaid in 1899); Turner River (1028).—Range, A. J.

#### GRIMMIACEAE

*Scouleria aquatica* Hook. Swifts Cannery (750).—Range, J.

Williams (1901) found this in the region about the head of Lynn Canal, and also at Dawson in Yukon.

*Scouleria aquatica nigrescens* Kindb. Ketchikan (4). New to Alaska. It was known to occur in southern British Columbia.

*Grimmia apocarpa rivularis* Web. & Mohr. (*Grimmia rivularis* Brid.; *Schistidium alpicola rivulare* Wahlenb.) Aats Bay, on rocks, altitude 300 meters (903).—Range, Y. J.

*Grimmia maritima* Turn. (*Schistidium maritimum* B. S. G.) Augustine Bay (547); Chinitna Bay (1311); Lewis Island, B. C. (1119); Mitrofanina Bay (1315); Northwest Harbor (1310); St. Paul Island (Kincaid in 1899); Shipley Bay (770 in part).—Range, B. A. P. S. Y.

Loeske, in his Grimmiaceae, records his observation that this is the only species of *Grimmia* in which the costa shows median guides. In a letter dated March 4, 1920, he points out that the costa in the Alaskan plants, some of which were submitted to him for verification, is less thick toward the apex than it is in plants from Europe, but that this is within the range of permissible variability. (Holzinger).

*Grimmia pachyphylla* Leiberg in Bull. Torr. Bot. Club 20: 113, 1893. Metlakatla (106). New to Alaska. We find no record of this except the original collection in Idaho.

*Grimmia trichophylla* Grev. Shell Island, B. C., on dry rocks, (1205).

*Racomitrium aciculare* (L.) Brid. (*Grimmia acicularis* C. Muell.) Ketchikan (2); Morse Cove (458 in part); Port Alice (725); Verdure Creek (29).—Range, P. J.

*Racomitrium canescens* (Weis.) Brid. (*Grimmia canescens* C. Muell.) Grewingk Glacier (1309).—Range, A. S. Y. J.

Renauld and Cardot (1892-1893) refer to its distribution as "Bering" etc., but probably this refers to the previous collection at Unalaska, in the Aleutian Island.



*Rhacomitrium canescens ericoides* (Web.) B. S. G. Shipley Bay (771).—Range, A. Y. J.

*Rhacomitrium fasciculare* (Schrad.) Brid. (*Grimmia fascicularis* C. Muell.) Port Malmsbury (991); Wrangell (Engstrom in 1905).—Range, B. A. P. S. Y. J.

*Rhacomitrium heterostichum* (Hedw.) Brid. (*Grimmia heterosticha* C. Muell.) Baranof (1081); Brownson Bay, altitude 300 meters (492); Ketchikan (6); Shipley Bay (1337).—Range, A. J.

*Rhacomitrium lanuginosum* (Ehrh.) Brid. (*R. hypnoides* Willd.; *Grimmia hypnoides* Lindb.) Aats Bay (917); Cape Douglas (1335); Metlakatla (93); St. Paul Island (Kincaid in 1899); Snug Harbor (1336); Wrangell (1118).—Range, N. B. P. S. J.

*Rhacomitrium microcarpum* (Schrad.) Brid. (*Grimmia ramulosa* Lindb.) Port Malmsbury (977).—Range, B. J.

It was known from St. Paul Island (J. A. Macoun, 1899) and from the region at the head of Lynn Canal (Kurt, 1895).

*Rhacomitrium palmeri* Kindb. in Rev. Bryol. 23:19. 1896. (*R. microcarpum palmeri* Kindb.; *R. tenuinerve* Kindb.) Augustine Bay (570); Coal Harbor (Kincaid in 1899); Egg Harbor (856); St. George Island (Kincaid in 1899); St. Paul Island (Kincaid in 1899).—Range, B. J.

This was known from Alaska only from the islands in Bering Sea. It was however known also from several points in British Columbia.

*Rhacomitrium patens* (Dicks.) Hueb. Mitrofanina Bay (1338).—Range, A. P.

From Alaska it seems to have been known only from the Aleutian Islands, taking it that Renauld & Cardot (1892-1893) refer to the Aleutian collections as "Bering".

*Rhacomitrium sudeticum* (Funck) B. S. G. (*Grimmia microcarpa* C. Muell.) Cape Douglas (1315); Metlakatla (106); Mitrofanina Bay, altitude 460 meters (1307 in part, 1312, 1314); St. George Island (Kincaid in 1899). New to Alaska.

*Rhacomitrium sudeticum occidentale* (R. & C.) Frye in Bryologist 21: 3. 1918. (*R. heterostichum occidentale* Ren. & Card.; *R. occidentale* Ren. & Card.; *R. brevipes* Kindb.; *R. micropus* Kindb.) Augustine Bay (569). New to Alaska.

#### ORTHOTRICHACEAE

*Amphidium lapponicum* (Hedw.) Schimp. (*Amphoridium lapponicum* Schimp.; *Zygodon lapponicus* B. S. G.) Shuyak Island (1316).—Range, A. P. S. Y.

*Zygodon reinwardti* (Hornsch.) Al. Braun in Bruch, Schimper and Guembel's Bryol. Eur. III vel Monogr. pag. 9. Fide M. Dozy et J. M. Molkenboer, Bryologia Javanica, p. 109, tab. 87. Engler & Prantl's die Naturliche Pflanzenfamilien, p. 462. Brownson Bay (491). New to Alaska.

This is another immigrant from eastern Asia. It normally grows on the bark of trees, but is here recorded as growing on rocks. It is both synoicous and autoicous, a relation designated by Lindberg as heteroicous. It has the leaves coarsely dentate toward the apex. Limpricht, in Laubmoose II, p. 10, records two European species of *Zygodon* with leaves toothed toward the apex: *Zygodon viridissimus dentatus*, and *Zygodon gracilis*. Both are dioicous; the latter is, in addition, devoid of propagula among the rhizoids. There are other characters which exclude this Alaskan plant from these European species. The following comparison shows how it differs from *Zygodon gracilis*:

*Zygodon reinwardti*

*Zygodon gracilis*

- |  |  |
|--|--|
| 1. Heteroicous.  | 1. Dioicous.   |
| 2. Plants yellowish green.   | 2. Plants black-green.   |
| 3. Propagula present among the brown rhizoids.   | 3. Propagula none. (See Correns' "Untersuchungen", p. 117.)  |
| 4. Marginal leaf-cells as large as the rest.   | 4. Marginal leaf-cells throughout a little smaller than the rest.  |
| 5. Perichaetial leaves smaller, with elongated cells; quite different from the rest.   | 5. Perichaetial leaves not different.  |
| 6. Cells around the mouth of the capsule hardly different from those of the rest of the exothecium. (See fig. in Doz. & Molk., t. 87, No. 24.) | 6. Five or more rows of very small thick-walled cells around the mouth of the capsule decidedly different from the rest. (See fig. in Limpr. II, p. 15.) |
| 7. Spores 22-26 microns, granular.   | 7. Spores 12-14 microns, nearly smooth.  |
| 8. Costa smooth on back.   | 8. Costa papillose on back.  |

There were a number of old capsules with the peristome gone; one had the operculum dried on, but no peristome could be made out even in that capsule. The shape and 8 ribs of the capsule, the form of the operculum, as well as the areolation of the exothecium are as figured in the plate in Dozy & Molkenboer. The following is the briefer description found on page 9 of Bryologia Javanica, translated:

"Plant synoicous or polygamous, loosely caespitose, rather large, greenish-yellow; stem ascending, tomentose, rather stout, sparingly branched by innovations; leaves erect-open, oblong-lanceolate, wavy, at the top sparingly and strongly serrate, strongly keeled, mucronate by the excurrent costa; inner perichaetial leaves short, erect, lanceolate, acuminate, slightly toothed at apex; capsule long-necked, cylindric-oblong, furrowed when dry, microstome; operculum conic-subulate, oblique; peristome simple, (representing) the inner one of 16 short, lanceolate cilia."

To these may be added some of the characters indicated in the above comparison:

Propagula\* among the rhizoids; perichaetial leaves smaller and different from the stem leaves, with elongated cells, not papillose; cells of the exothecium nearly alike throughout; spores 22-26 microns, granular. (Holzinger).

*Orthotrichum alpestre* Hornsch. St. Paul Island (Kincaid in 1899). New to Alaska. Williams (1901) found it in Yukon at Dawson, and also at Lake Marsh in southern Yukon. John Macoun (1902) mentions its occurrence in southern British Columbia. It would not be surprising therefore if it were found in almost any region in Alaska.

*Orthotrichum obtusifolium* Schrad. Kodiak (Mylroie in 1911).—Range, P. J.

Williams (1901) found this in southern Yukon; and at Skagway, Alaska. It is known from British Columbia (John Macoun, 1892, 1902).

*Orthotrichum speciosum* Nees. Kodiak (Mylroie in 1911).—Range, P. J.

This was known from Alaska only from the southeastern portion.

*Uloa alaskana* Card. & Ther. in Proc. Wash. Acad. Sci. 4: 293-372. 1902. Mitrofan Bay (1360).—Range, P. S. Y. J.

Gladhaugh Bay (Virgin Bay) is the most westerly point from which it was known.

*Uloa bruchii* Hornsch. in Brid. Bryol. univ. I, p. 794, 1826. (*Heisia bruchii* Lindb.) Brownson Bay (466); Egg Harbor (947); Ratz Harbor (310); Swifts Cannery (756); Tam Gas Harbor (121).—Range, J.

*Uloa crispa* (Hedw.) Brid. Juneau (Shumway in 1891, Mehner in 1904); Kanaganut Island (39); Lazy Bay (1363); Lewis Island, B. C. (1187); Nichols Bay (383, 387); Port Malmesbury (998); Shipley Bay (1185); Swanson Bay, B. C. (1186).—Range, P. J.

\*Correns, C. Untersuchungen ueber die Vermehrung der Laubmoose Jena, 1899.

Its discovery at Mitrofanía Bay is a considerable extension of range, since from Alaska it was known only from the southeastern portion.

*Ulota phyllantha* Brid. (*U. maritima* C. Muell. & Kindb.; *Weisia phyllantha* Lindb.) Augustine Bay (568); Egg Harbor (855); Nichols Bay (383); Tam Gas Harbor (120).—Range, B. A. P. Y. J.

#### SPLANCHNACEAE

*Tayloria serrata* (Hedw.) B. S. G. Baranof (1090); Brownson Bay (506); Ketchikan (512); Port San Antonio (unnumbered); Swifts Cannery (754, 781).—Range, B. J.

*Tayloria tenuis* (Dicks.) Schimp. Metlakatla (94).—Range, S. Y. J.

*Tetraplodon mnioides* (Swartz) B. S. G. (*T. bryoides* Lindb.) Baranof (1090 in part); Lazy Bay (1364); Popoff Island (Kincaid in 1899); St. George Island (Kincaid in 1898).—Range, N. B. A. P. Y. J.

*Tetraplodon urceolatus* (Brid.) B. S. G. Baranof (1090 in part); Brownson Bay (468).—Range, N. B. J.

This was known from Alaska only from Bering Sea and the Arctic shore. Williams (1901) found it near Dawson, Yukon.

#### FUNARIACEAE

*Funaria hygrometrica* (L.) Sibth. Tanana (O. Clark in 1910).—Range, T. B. J.

*Funaria hygrometrica arctica* Berggren in Kon. Sven. Vet.-Akad. Handl. 13, N. 7, p. 57. 1874. Calder (826). New to Alaska. Williams (1901) found it in the Dawson region of Yukon.

The annulus rolls off spirally; lid bordered with orange; shape of capsule as in the typical form, but the six rows of rectangular cells around the mouth, described in Limpricht II, p. 200, for the species, are not clearly made out; they shade into the orange rim of the operculum; spores 20-28 microns, rough-granular; leaves short, only about twice as long as wide, tightly rolled together to form an elongated bud, the equally wide costa entering the short point; the perichaetial leaves, which are serrate at apex in the species, here are practically entire. (Holzinger).

#### BBYACEAE

*Leptobryum pyriforme* (L.) Schimp. (*Bryum pyriforme* Hedw.) Dawson in Yukon (O. Clark in 1910).—Range, B. A. S.

*Webera annotina* (Hedw.) Bruch. Juneau (Mehner in 1904). New to Alaska. This plant shows abundant orange-colored gemmae in the leaf axils (Correns, Verm. d. Laubm., p. 165).

*Webera canaliculata* C. Muell. & Kindb. in Macoun's Catalog Canadian Plants, No. 6, p. 113. 1892. Ex Char. Sinuk (Hill in 1915).—Range, B. A.

Unalaska is the only Alaskan point from which it was known (John Macoun, 1902), although known from British Columbia. The inflorescence of these plants is strictly synoicous, antheridia and archegonia both numerous in the same bud; cilia 1 or 2, nodulose segments gaping.

*Webera cruda* (L.) Bruch. (*Pohlia cruda* Lindb.; *Bryum crudum* Schreb.) Juneau (Mehner in 1904); St. Paul Island (Kincaid in 1899).—Range, B. A. P. J.

*Webera cucullata* (Schwaegr.) Schimp. St. George Island (Kincaid in 1898).—Range, B.

Known from Alaska only from St. Paul Island (J. A. Macoun, 1899), although known from British Columbia.

*Webera longicolla* (Swartz) Hedw. Sp. Musc. p. 169, t. 41, f. 1-5, 1801. Baranof (1089 in part). New to Alaska. Reported from the Cascade Mountains (John Macoun, 1892), probably near the 49th parallel of latitude.

*Webera ludwigii latifolia* Schimp. Syn. 2 ed., p. 402, 1876. Sinuk (Hill in 1915). New to Alaska. This variety is known sterile only. It was compared with a plant from Wyoming, determined by Cardot.

*Webera nudicaulis* (Lesq.) Lesq. & James, Manual p. 220, 1884. Port Chatham (1362). New to Alaska.

*Webera nutans* (Schreb.) Hedw. (*Pohlia nutans* Lindb.; (*Bryum nutans* Schreb.) Baranof (1087); Cape Douglas (1318); Juneau (Shumway in 1891); St. George Island (Kincaid in 1898); Seward (1361).—Range, N. B. A. P. S. J.

*Bryum agattuense* Philibert in Rev. bryol. 1901, p. 35. Ex char. St. George Island (Kincaid in 1898); St. Paul Island (Kincaid in 1899).—Range, B. A.

This was known only from Agattu Island (Philibert, 1901).

*Bryum arcticum* (R. Br.) B. S. G. St. Paul Island (Kincaid in 1899); Stepovak Bay (1317).—Range, B. P.

*Bryum argenteum* L. Calder (863); Juneau (Mehner in 1904); Popoff Island (Kincaid in 1899).—Range, B. A. P. J.

Its known Alaskan range was limited to the Bering Sea and bounding islands and shores.

*Bryum binum* Schreb. Calder (861); Shell Island, B. C. (1189).—Range, J.

*Bryum caespiticium* L. Sp. pl. p. 1121 (1753) sed non L. Herb. (See Limpricht's footnote under *Webera nutans*). Izhut Bay (1365).—Range, P. J.

*Bryum duvalii* Voit. Kodiak (Myroie in 1911).—Range, A. P. S. Y.

*Bryum inclinatum* (Sw.) B. S. G. St. Paul Island (Kincaid in 1898); Seldovia (1366).—Range, N. B. A. P. S. Y. J.

*Bryum lacustre* Bland. Musc. exs. fasc. III, No. 132. 1804. Grewingk Glacier (1367); St. Paul Island (Kincaid in 1898).—Range, N. B. P. S.

*Bryum laurentianum* Card. & Ther. in Proc. Wash. Acad. Sci. 4: 320. 1902. Mitrofan Bay (1320).—Range, B. P.

*Bryum pallens* Swartz. Ketchikan (O. Clark in 1910).—Range, Y. J.

*Bryum pallescens* Schleich. Calder (825); Kodiak (Myroie in 1911); Mitrofan Bay (1368).—Range, B. P. A. S. Y. J.

*Bryum purpurascens* (R. Br.) B. S. G. in Bryol. Eur. Fasc. 32, Suppl. I, P. II, p. 107, t. 75. 1816. St. Paul Island (Kincaid in 1898-1899. New to Alaska. It is rather widely distributed in the colder regions of Canada.

*Bryum turbinatum* (Hedw.) Schwaegr. Suppl. I, P. II, p. 109 (1816). Port Chatham (unnumbered). New to Alaska. It is known from British Columbia and Northwest Territory in Canada.

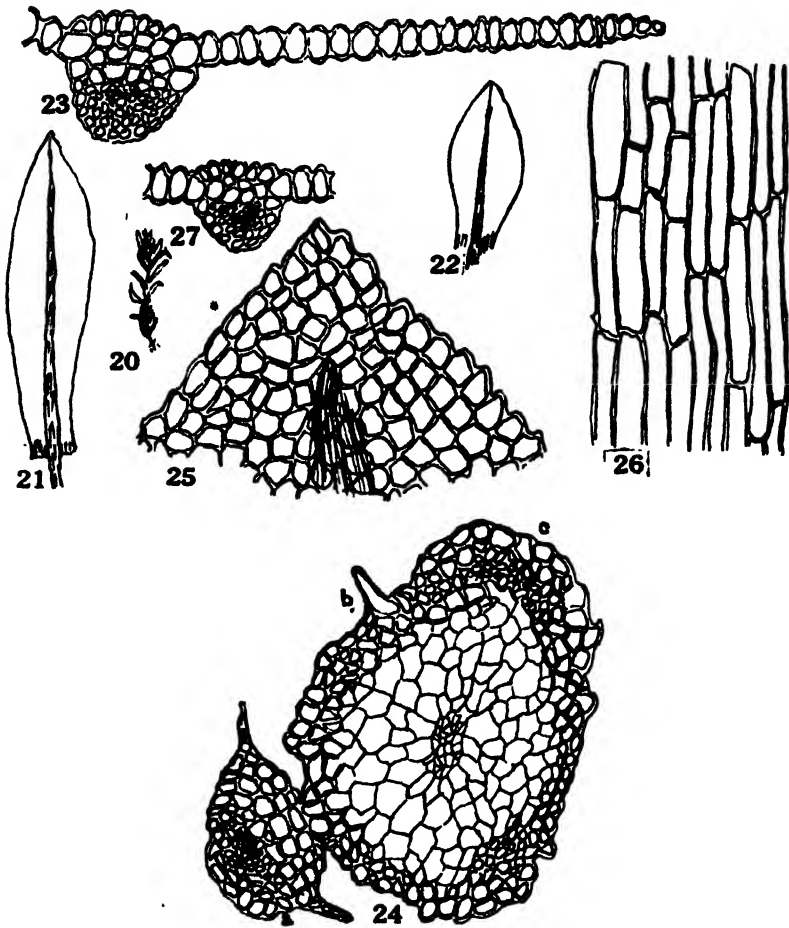
#### MNIACEAE

TRACHYCYSTIS Lindb. in Not. Fl. Fenn. 9, p. 80, 1868.

Dr. Brotherus, in Engler & Prantl, p. 607, makes this a section under the genus *Mnium*. There are 2, possibly 3, species included in this group, which is so characteristically marked by mamillae (not "papillae", as in Engler & Prantl, p. 607) on both sides of the lamina that it seems desirable to give to Lindberg's group-name full generic value.

*Trachycystis flagellaris* (Sull. & Lesq.) Lindb. in Contrib. ad Fl. Crypt. As. bor. or., p. 241. 1872 (see Paris Index). *Mnium flagellare* Sull. & Lesq. in Proc. Amer. Acad. Arts and Sci., 1859, p. 272. Shuyak Island (1321).—Range, P.

The first collection of this plant in North America was by Miss Ruth Myroie in 1911 on Kodiak Island, Alaska (Williams, 1912). The plant was first collected on the North Pacific Exploring Expedition



## PLATE 7

*Bryobrittonia pellucida*, redrawn from Bull. N. Y. Bot. Gard. 2:pl. 16.

Fig. 20. Plant; about  $\times 8$ . Fig. 21. Upper stem leaf;  $\times 6.6$ . Fig. 22. Lower stem leaf;  $\times 6.6$ . Fig. 23. Cross section of leaf;  $\times 132$ . Fig. 24. Cross section of stem: a, section of costa at point where it joins stem; b, a rhizoid growing out from stem; c, lower part of costa where it is wholly adnate to the stem;  $\times 132$ . Fig. 25. Apex of leaf;  $\times 236$ . Fig. 26. Leaf cells at margin, a little above the base;  $\times 236$ . Fig. 27. Cross section of costa;  $\times 132$ .

by Charles Wright in 1855 at Hakodade, Yesso, Japan. Previous to Miss Mylroie's discovery of it, this species was known only from the above type locality in Japan, from the Amoor River basin and from

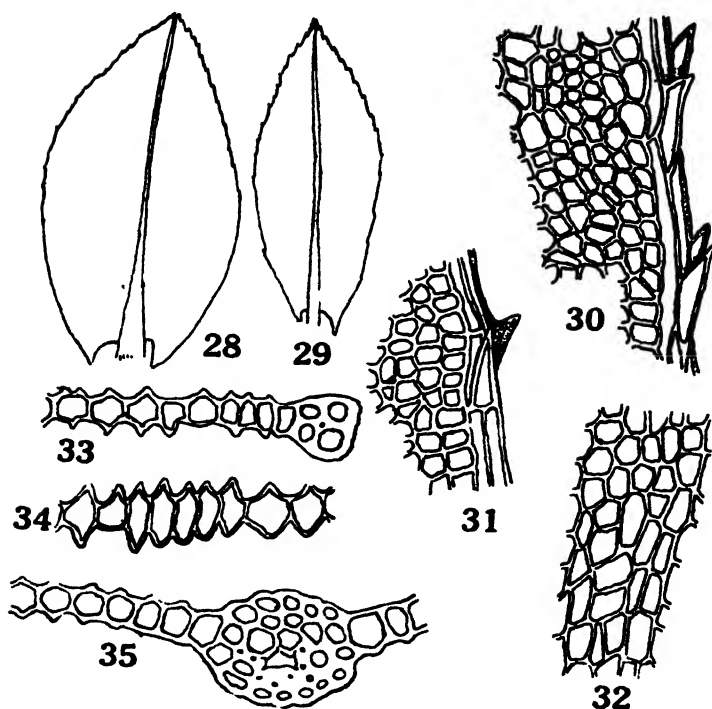


PLATE 8

*Trachycystis flagellaris*, drawn from No. 1321.

Fig. 28. Leaf from upper part of old stem just below corall head;  $\times 25$ .  
 Fig. 29. Leaf from median portion of sterile stem;  $\times 25$ . Fig. 30. Margin of leaf in Fig 2, upper  $\frac{3}{4}$ ;  $\times 250$ . Fig. 31. Margin of leaf in Fig. 1, upper  $\frac{3}{4}$ ;  $\times 250$ .  
 Fig. 32. Arecolation of leaf in Fig. 1 at lower median insertion;  $\times 250$ . Fig. 33. Cross section of margin of mature leaf from plant bearing flagella;  $\times 250$ . Fig. 34. Cross section through middle of leaf from young sterile stem;  $\times 250$ . Fig. 35. Costal section, about median, of mature flagella-bearing leaf;  $\times 250$ .

Saghalin Island. Dr. Brotherus, in Engler & Prantl's Nat. Pflanzenf., I, p. 607, places the plant under *Mnium*, thus:

"Sect. I. *Trachycystis* (Lindb.) Mitt. in Trans. Linn. Soc. 2 Ser. Bot. III. p. 169. (*Trachycystis* Lindb. in Not. F. Fl. fenn. IX. p. 80 1868, as genus.) Dioicous. Leaves with margin of thickened cells doubly serrate, or without margin and a single row of teeth. Costa with a layer of median guides, a small star-shaped group of companion cells and a dorsal stereid band; cells with a large papilla on both sides."



Dr. Brotherus assigns to this section, besides this plant from Japan and Alaska, another species from Japan and China, *Mnium microphyllum* Dozy & Molk.

Mr. R. S. Williams in Bull. N. Y. Bot. Garden 2: 115, pl. 16, 1901, describes and figures *Bryobrittonia pellucida* from Yukon, which fits fairly into the generic description of *Trachycystis*. True, his plant is not margined; but neither is *Mnium microphyllum*. The structure of the costa shows essential agreement, judging from the figures, both drawn by Mr. Williams, the first in 1901, the second in 1911. The essential difference here is in the ventral cells of the costa, which in *Bryobrittonia* are large and mamillate like the cells of the lamina. The mamillae are absent in the costa of *Mnium flagellare* figured in the Bryologist.

Dr. Brotherus in Nat. Pflanzenf., p. 413 and 427, places *Bryobrittonia pellucida* under Pottiaeae, following the author. This position seems abnormal. The structure of the costa would not exclude it from Mniaceae. The leaves strongly mamillate on both sides (see figures in the Bryologist and in Bull. N. Y. Bot. Garden) seem to bring it safely under the Lindbergian genus *Trachycystis*, as *T. pellucida*, distinguished from the two Asiatic species by the elongated cells of the leaf-base (not unknown in the Mniaceae), and by the mamillate cells of the costa, continuous with those of the lamina. The author's description "Terminal leaves (often enclosing numerous paraphysis-like hairs)", also tends to support the reference of this plant to Mniaceae.

Paris' Index, 5: 194, 1906, unites *Trachycystis flagellaris* with Bridel's genus *Rhizogonium*. But, apart from several characters excluding the plant from Rhizogoniaceae, the shape of the operculum forbids this reference. Dr. Brotherus in Engler & Prantl's Nat. Pflanzenf., 1: 614, gives for Rhizogoniaceae, "operculum obliquely beaked, rarely conic"; Lindberg, in Acta Societatis Scientiarum Fennicae 10: 241, 1875, gives the operculum of *Trachycystis flagellaris* as "hemispherical, distinctly mamillate." The reference of this plant to *Rhizogonium* is therefore not well founded.

By the courtesy of Prof. E. B. Chamberlain I am able to quote in full Dr. S. O. Lindberg's description, in his article, Contributio ad Floram Cryptogamiam Asiae Borealis-orientalis, comprising pages 221-280 in Acta Societatis Scientiarum Fennicae, Vol. 10. It was presented to the Society on Feb. 15, 1872, but was not printed until 1875. On page 241 we read (translated):

"29. *Trachycystis flagellaris* (S. & L.). Dioicous, of the habit of *Mnium orthorrhynchum*, up to 2 cm. high, producing at the end, be-

low both perichaetium and androecium, abundant flagella, which are erect, stiff and very fragile, bearing very minute (very rarely true) leaves; leaves distant, inclined to obtuse, with margin plane, border thickened, from below the middle regularly doubly serrate, the costa reaching the apex and smooth on the back, the (laminal) cells quite large, sub-quadrate, papillose.

"Stations: near Tunai, sterile, middle of September, 1860, Schmidt; near Dui, female and fruiting, May 30, 1861, also Kussemai, sterile, middle of June, 1861, Glehn. It also occurs in Amooria and Japan.

"Seta 1.502 cm. long, purple-yellow, flexuous and twisted to the right, very smooth. Capsule 3-3.5 mm. long and 1.5 mm. in diameter, oblong, horizontal, curved, smooth, yellowish, wrinkled and opaque when dry, leptoderm, with regular hexagonal cells, loose, very smooth, with numerous superficial stomata at base of capsule. Annulus absent (there was only a single perfect capsule). Outer peristome straw-yellow; inner brown, its segments gaping widely and keeled; cilia yellow, in threes, equally long, shortly nodulose, frequently quite distinctly appendiculate. Operculum hemispherical, distinctly mamillate, —Paraphyses of androecium very numerous, long, filiform, sharp-pointed, slightly thickened toward top."

Professor Chamberlain observes that page 241 is in the sub-title Musci Sachhalenses collecti a cll. p. von Glehn & F. Schmidt; that the species is also mentioned among the Musci Amurenses collected by Maximowicz & Schmidt; and is listed by Lindberg & Arnell in Musci Asiae Borealis, II, Laubmoose, in Kgl. Svensk. Vet. Akad. Handl., Bd. 23, No. 10, p. 23.

Dr. C. Correns in his exceedingly valuable treatise, Vermehrung der Laubmoose, p. 203, 1899, discusses the vegetative flagella using Lindberg's name *Trachycystis flagellaris* (Sulliv. & Lesq.) Lindb.

The Alaska plant grew in a substratum of volcanic ash in which it was nearly submerged. (Holzinger).

*Leucolepis acanthoneura* (Schwaeg.) Lindb. (*Mnium menziesii* Hook.) Aats Bay (933); Augustine Bay (551); Ketchikan (8); Morse Cove (462); St. John Harbor (236); Saltery Cove (325); Swifts Cannery (710, 751); Tam Gas Harbor (138).—Range, J.

*Mnium affine* Bland. Aats Bay, altitude 300 meters (905); Juneau (Mehner in 1904); Port San Antonio (648); Tongass Island (53).—Range, A. P. J.

*Mnium cinclidioides* (Blytt) Hueb. Port Chatham (1311).—Range, S. J.

This was known from Alaska only from Douglas Island (Cardot & Theriot, 1902). These plants from Port Chatham seem to be young, as appeared from comparison with young plants collected by Dr. N. Bryhn near Hoenefoss, Norway.

*Mnium glabrescens* Kindb. in Note on Canadian Bryology, in 1893. (See John Macoun, 1902). Kodiak (Mylroie in 1910).—Range, B. P. S. J.

*Mnium insigne* Mitt. Wrangell (Engstrom in 1905).—Range, B. A. J.

*Mnium medium* B. S. G. Augustine Bay (566); Swifts Cannery (689).—Range, Y. J.

*Mnium nudum* R. S. Williams in Bryologist 3: 6, 1900. (*Mnium punctatum nudum* Card. & Ther.) Turner River (1034).—Range, A. Y. J.

*Mnium punctatum* (L.) Hedw. (*Astrophyllum punctatum* Lindb.) Augustine Bay (556); Hidden Inlet (70); Juneau (Shumway in 1891); Ketchikan (11); Lake Bay (217); Morse Cove (461); Nichols Bay (378); Northwest Harbor (1309); Port Chatham (1307); St. John Harbor (252); Shuyak Island (1308); Swifts Cannery (706); Tam Gas Harbor (114).—Range, A. P. S. Y. J.

*Mnium spinosum* (Voit) Schwaegr. Suppl. I, P. II, p. 130, No. 10, t. 78, 1816. Aats Bay, altitude 300 meters (924). New to Alaska.

*Mnium subglobosum* B. S. G. Alimvoak Bay (1310); Juneau (Mehner in 1904); Wrangell (Engstrom in 1905).—Range, B. P. S. Y. J.

Much confusion exists in regard to this species. It is usually referred by error to *Mnium punctatum*, J. K. Small's plant from Pa., Mrs. M. L. Steven's plant from Antrim, N. C., Dr. Grout's from Vermont, Miss S. F. Sanborn's from York, Me., Underwood's from Syracuse, N. Y., and his No. 11, all called *Mnium punctatum*, belong here; so does a plant from C. Jensen, Hvalsoe, Denmark, named *Astrophyllum pseudopunctatum* (B. S.) Lindb.

#### AULACOMNIACEAE

*Aulacomnium androgynum* (L.) Schwaegr. Augustine Bay ((1184 in part); Juneau (Shumway in 1891).—Range, P. J.

*Aulacomnium androgynum pygmaeum* n. var. Mitrofan Bay (1320 in part).

Growing among the plants of a sterile Bryum. Whole plant 8-10 mm. long; lower part of stem 4-5 mm., bare of leaves, with traces of rhizoids; leaf-bearing part 3 or more mm., forming a bud; pseudopodium 2 mm. long; capitulum 1.25 mm. in diameter; gemmae 40

by 85 microns, their stems 5-6 microns thick. (See Correns Vermehrung der Laubmoose, p. 217, fig. H.)

The leaves are three-fourths as long as in *A. androgynum*; apex not so strongly erose-dentate; lamina more flat; margin below erose apex frequently dentate to below the middle by projection of cells. Quite sterile.

Distinguished by its diminutive size, by the scanty rusty rhizoids, short flat leaves which are frequently dentate to below the middle, and quadrate or rectangular basal leaf cells. (Holzinger).

*Aulacomnium palustre* (L.) Schwaegr. Baranof (1072); Brownson Bay (647); Juneau (Shumway in 1891, Mehner in 1904); Kodiak (Myloie in 1910); Lazy Bay (1342); Metlakatla (103); Sinuk (Hill in 1915); Tam Gas Harbor (116); Tanana (O. Clark in 1911); Three Saints Bay (1272, 1339, 1340); Wrangel (1204); Yakutat Bay (1341).—Range, N. T. B. P. Y. J.

*Aulacomnium turgidum* (Wahlenb.) Schwaegr. Dawson (O. Clark in 1910); Kodiak (Myloie in 1911).—Range, N. P. B. J.

#### BARTRAMIACEAE

*Plagiopus oederi* (Gunn.) Limpr. in Laubm. II, p. 548, 1895. (*Bartramia oederiana* Swartz; *Bartramia oederi* Swartz, of Cardot & Thériot in Harriman Alaska Expedition 5: 247, 1910). Juneau (Mehner in 1904).—Range, S. J.

*Bartramia breviseta* Lindb. in Not. ur Saelsk p. Fauna et Flora Fenn. foerh. 9, p. 255. 1868. St. Paul Island (Kincaid in 1899). New to Alaska.

Plants synoicous, 1-1.5 cm. high. Leaves brittle, erect, rigid when dry, when wet they assume the same position, slightly diverging; seta 1 cm. long; capsule erect, wrinkled longitudinally; lid low, umbonate; peristome of 16 rudimentary teeth with 3-5 joints, somewhat irregular; spores brown, 32-40 microns, round and kidney-shaped, rough-warty; mouth of capsule with 3-5 rows of darker brown flattened cells

The leaves have a sheathing base with the lamina of one layer of cells; costa well defined and about one-fifth of the lamina; above the sheathing base the costa spreads out toward the margin of the lamina, and a distinction between costa and lamina is not possible; in the region of the costa are 5-6 layers of nearly uniform cells with walls of medium thickness; there are no clearly defined guides, nor stereid bands; these cell layers run to a wedge toward the margin, diminishing in number so that the leaf section takes the form of a crescent, the margin consisting of a single layer of 2-3 rows of minute

cells, making almost a knife edge; below the middle of the leaf both surfaces are mamillöse, above the middle they are papillose by elongation of the mamillae, each cell bearing a papilla.

The description of this species in Limpricht's Laubmoose II requires the leaves to curl, while in this plant they are straight. Also both Limpricht and Barnes' Key assign a very short seta, overstopped by the uppermost leaves, to this species, while Dr. Brotherus in Engler & Prantl. p. 638, figures *B. breviseta* with capsule exserted; also leaf and leaf-apex exactly as found in the Alaska plant, contradicting the diagnostic legend "capsule immersed." Dr. Brotherus shows the costa filling the width of the lamina above the sheathing base the same as in this plant.

Dr. I. Hagen, in Musci Norvegiae borealis, p. 248, treats *B. breviseta* as a variety of *B. ithyphylla*. Leaf sections of *B. ithyphylla* show the lamina composed of two cell layers, and distinctly marked off from the costa, with both surfaces papillose. *B. viridissima* (*B. subulata*) collected by Holzinger on Pike's Peak, Colorado, has leaf sections like *B. breviseta*, but shows distinct guides in the region of the costa. It also differs from the Alaska plant in size and scant rhizoids. These two plants appear to make a very distinct section of the genus *Bartramia*, and Dr. Hagen's reference of *B. breviseta* to a variety of *B. ithyphylla* seems impossible. (Holzinger).

*Bartramia glaucoviridis* C. Muell. & Kindb. Brownson Bay (506); Hidden Inlet (82); Morse Cove (458); Port Alice (729); St. John Harbor (233, 239); Seward (1322, 1323); Shipley Bay (792); Swanson Bay, B. C. (488). New to Alaska.

*Bartramia ithyphylla* (Haller) Brid. Mitrofanina Bay (1276).—Range, B. A. P. S. J.

*Bartramia pomiformis* (L.) Hedw. Aats Bay (934); Juneau (Mehner in 1904); Popoff Island (Kincaid in 1899); Shipley Bay (1188).—Range, B. P. S. J.

*Philonotis arnellii* Husnot in Musc. Gall. p. 268. Description in Rev. bryol. pp. 14-15, 1894, in article by Philibert, p. 2-15. Also in Limpricht's Laubmoose, II, p. 562. Ketchikan (514). New to Alaska.

This Alaskan plant has developed in the leaf axils great numbers of "bruchaeste," which are short branches easily detached, and which accumulate in the pocket as emerald-green powder. (See Corren's Vermehrung der Laubmoose, p. 149.)

A number of species and varieties of *Philonotis* are established on sterile material: *P. tenella* (C. Muell.) Jaeg. (*P. muhlenbergii tenella* Brid.), *P. tenella coloradensis*, and Canadian Musci No. 152 named *P. macounii* Kindb., are very close, almost indistinguishably close to each other. A plant from upper Italy sent by Artaria, and one from

C. Jensen collected near Hvalsoe, Denmark, and named *C. capillaris* Lindb., seem to be identical with this Alaskan plant. The burden of Philibert's article above quoted seems to be to try to bring some system into the chaos of these closely related sterile "species". To gain his point he finds himself compelled to propose two additional species, *P. ryani* and *P. parvula*.

Measurements of the leaves and leaf cells of the Alaskan plant agree with data given by Philibert, l. c. page 13. But antheridia reported as only 270-340 microns long for *P. arnellii*, here measure 600-650 microns. However, the dissection of a less mature antheridial bud yielded antheridia of exactly the same size as described for *P. arnellii*. Philibert probably measured immature antheridia. The distinctive characters of *P. arnellii* claimed by Philibert, all of which are found in the Alaskan plant, are as follows: 1. Stems more delicate and longer. 2. Stem leaves more distant, narrowed to base and decurrent. 3. Male bracts more spreading, longer and narrower, with costa well marked and reaching or passing beyond the apex. (Holzinger).

*Philonotis fontana* (L.) Brid. Alimvoak Bay (1278); Juneau (Mehner in 1904); Kodiak (1369).—Range, B. A. P. Y. J.

*Philonotis fontana seriata* (Mitt.) Breidl. (*Bartramia seriata* Mitt.; *Philonotis seriata* Lindb.) Juneau (Mehner in 1904 and 1905); Kodiak (Mylroie in 1910 and 1911); Lazy Bay (1324); Mitrofan Bay (1370); Uzinki (1325).—Range, P. J.

*Philonotis muhlenbergii* (Schwaegr.) Brid. Juneau (Mehner in 1904). New to Alaska.

#### TIMMIACEAE

*Timmia austriaca* Hedw. St. Paul Island (Kincaid in 1899).—Range, B. J.

This was known from Alaska only from the southeastern part, although Williams (1901) found it in the Dawson region of Yukon.

#### GEORGIACEAE

*Georgia geniculata* (Girgh.) Lindb. (*Tetraphis geniculata* Girgh.) Aats Bay (910); Augustine Bay (671); Exchange Cove (269); Hunts Cannery (948); Juneau (Shumway in 1891); Port San Antonio (607, 1099); Sitklan Island (42); Swifts Cannery (708).—Range, S. J.

*Georgia pellucida* (L.) Rabenh. (*Tetraphis pellucida* Hedw.) Juneau (Mehner in 1905).—Range, J.

## POLYTRICHACEAE

*Catharinea undulata* (L.) Web. & Mohr. (*Atrichum undulatum* Beauv.) Calder (833).—Range, J.

*Oligotrichum aligerum* Mitt. Port Malmsbury (996).—Range, P. J.

This was known from Alaska only from Kodiak (Cardot & Theriot, 1902).

*Oligotrichum parallelum* (Mitt.) Kindb. (*Atrichum parallelum* Mitt.; *Atrichum leiophyllum* Kindb.) Baranof (1224).—Range, S. J.

*Bartramiopsis lescurii* (James) Card. & Ther. (*Atrichum lescurii* James; *Bartramiopsis sitkana* Kindb.) Egg Harbor (944); Port Malmsbury (983); Swanson Bay, B. C. (1100); Wrangell, (1102, 1103, Engstrom in 1904 and 1905).—Range, S. J.

Japan, Kamchatka and Alaska. The most southern American location known was Sitka. Its discovery at Swanson Bay, B. C., extends its range about 650 kilometers (about 400 miles) to the southeast. (See Holzinger, 1920).

*Pogonatum alpinum* (L.) Roehl. (*Polytrichum alpinum* (L.) Baranof (1094); Brownson Bay (486, 518); Calder (834); Ketchikan (12, O. Clark in 1910); Nichols Bay (394); St. George Island (Kincaid in 1899); St. Paul Island (Kincaid in 1899); Shipley Bay (775); Woewodski Island (968).—Range, N. B. A. P. S. Y. J.

*Pogonatum alpinum arcticum* (Swartz) Brid. Seward (1239).—Range, S. Y.

*Pogonatum alpinum brevifolium* (Muell.) Brid. Mitrofanía Bay (1242); St. Paul Island (Kincaid).—Range, B. P.

*Pogonatum alpinum macounii* (Kindb.) Card. & Ther. (*P. macounii* Kindb.) Augustine Bay (560); Egg Harbor (944 in part); Juneau (Shumway in 1891, Mehner in 1904); Lake Bay (207); Morse Cove (449); Nichols Bay (379); Port Malmsbury (1002); Port San Antonio (611); Sitka (Shumway in 1891); Swifts Cannery (716); Tam Gas Harbor (139).—Range, J.

This is the most common *Pogonatum* in southeastern Alaska.

*Pogonatum alpinum septentrionale* (Swartz) Brid. (*Pogonatum alpinum microdontium* Kindb.; *Polytrichum microdontium* Kindb.) St. Paul Island (Kincaid in 1899).—Range, B. P.

*Pogonatum capillare* (Rich.) Brid. (*P. dentatum* Brid.; *P. capillare dentatum* Lindb.) Baranof (15, 1085); Douglas (L. Clark in 1908); Juneau (Shumway in 1891, Mehner in 1904); Ketchikan (500, 511); Kodiak (Mylroie in 1910); Mitrofanía Bay (1319 in part); Port Chatham (1240); Prince Rupert, B. C. (Foster in 1913); Woewodski Island (966); Wrangell (1214).—Range, N. B. A. P. S. J.

*Pogonatum contortum* (Menz.) Lesq. (*P. atrovirens* Mitt.; *P. erythrodontium* Kindb.) Baranof (1105); Calder (830, 866); Egg Harbor (939); Nichols Bay (393); Port Malmesbury (987, 1104); St. John Harbor (242); Swanson Bay, B. C. (1101); Swifts Cannery (699); Woewodski Island (963); Wrangell (1213).—Range, P. S. J.

*Pogonatum urnigerum* (L.) Beauv. Cape Douglas (1237); Mitrofan Bay (1241); Turner River (1036).—Range, P. S. Y. J.

*Polytrichum attenuatum* Menz. (*P. formosum* Hedw.) Augustine Bay (564); Baranof (1095); Calder (831); Exchange Cove (264); Lake Bay (212); Port San Antonio (620); Swanson Bay, B. C. (1211); Tongass Island (52); Woewodski Island (1117); Wrangell (1209, 1223).—Range, P. S. Y. J.

*Polytrichum commune* L. Dawson, Yukon (Henwick in 1900); Kodiak (Townsend in 1888); Tanana (O. Clark in 1911).—Range, T. P. J.

*Polytrichum commune uliginosum* Hueb. Tanana (O. Clark in 1911). New to Alaska.

*Polytrichum gracile* Dicks. Baranof (1106); Sinuk (Hill in 1915).—Range, N. B. P. J.

*Polytrichum jensenii* Hag. Tanana (O. Clark in 1911).—Range, T. N.

It was known from Alaska only from Nome.

*Polytrichum juniperinum* Willd. Chinitna Bay (1235, 1236); Dawson, Yukon (Henwick in 1900, O. Clark in 1910); Douglas (L. Clark in 1908); Ketchikan (515); Kodiak (Mylroie in 1910 and 1911); Lazy Bay (1238); Morse Cove (436); Shell Island, B. C. (1210); Shipley Bay (1212); Tanana (O. Clark in 1910); Woewodski Island (965).—Range, N. T. B. P. S. J.

*Polytrichum piliferum* Schreb. Brownson Bay (484). All the previous reports with which we are familiar are merely "Alaska".

*Polytrichum strictum* Banks. (*P. juniperinum strictum* B. S. G.; *P. beringianum* Kindb.) Augustine Bay (1305); Baranof (1089 in part); Brownson Bay (475); Cape Douglas (1333); Dawson, Yukon (Henwick in 1900); Metlakatla (100); Morse Cove (457); Tanana (O. Clark in 1911); Wrangell (1207, 1208).—Range, N. T. B. P. S. J.

#### HEDWIGIACEAE

*Hedwigia albicans* (Web.) Lindb. (*H. ciliata* Ehrh.) Turner River (1029). New to Alaska, although found by Williams (1901) in Yukon, both in the southern portion and the Dawson region.



## FONTINALACEAE

*Fontinalis neo-mexicana* Sull. & Lesq. Popoff Island (Kincaid in 1899). New to Alaska. *F. patula* (Cardot & Theriot, 1892) and *F. antipyretica* (Kurtz, 1895) have both been found in Alaska, but only in the southeastern portion.

## CLIMACIACEAE

*Climacium dendroides* (L.) Web. & Mohr. Juneau (Shumway in 1891); Kodiak (Myroie in 1910); Stepovak Bay (1277); Tanana (O. Clark in 1911).—Range, T. B. P. Y. J.

*Climacium ruthenicum* (Weinm.) Lindb. (*Hypnum ruthenicum* Weinm.) Juneau (Shumway in 1891, Mehner in 1905).—Range, B. A. S. Y. J.

## LEUCODONTACEAE

*Antitrichia curtipendula* (L.) Brid. Hidden Inlet (69); Snug Harbor (1265).—Range, A. P. S. Y. J.

*Antitrichia curtipendula gigantea* Sull. & Lesq. (*A. gigantea* Kindb.) Aats Bay (783); Alimvoak Bay (1266); Augustine Bay (557); Hidden Inlet (77); Kanaganut Island (40); Kodiak (Myroie in 1910 and 1911); La Touche Island (Birkett in 1907); Lazy Bay (1269); Lewis Island, B. C. (1109); Metlakatla (110); Morse Cove (459); Ratz Harbor (306); Seward (1267, 1270); Shipley Bay (1108); Shuyak Island (1271); Snug Harbor (1264); Swifts Cannery (711); Three Saints Bay (1268).—Range, A. P. S. Y. J.

## NECKERACEAE

*Neckera douglasii* Hook. Hidden Inlet (66, 72, 88); Port San Antonio (650); St. John Harbor (237); Tam Gas Harbor (122).—Range, J.

*Neckera menziesii* Hook. Ketchikan (679).—Range, J.

*Thamnum alopecurum* (L.) B. S. G. (*Porotrichum alopecurum* Mitt.) Aats Bay (928). New to Alaska.

## HOOKERIACEAE

*Pterygophyllum lucens* (L.) Brid. Augustine Bay (555, 675); Brownson Bay (480); Egg Harbor (941); Hidden Inlet (74); Lake Bay (195); Nichols Bay (395); St. John Harbor (244); Saltery Cove (332); Swanson Bay, B. C. (1110).—Range, S. J.

This was known from Alaska from Port Etches (John Macoun, 1902). While it is nowhere a conspicuous feature of the flora, it can-

not be rare in southeastern Alaska or it would not have been found in 8 widely separated localities.

#### HYPOPTERYGIACEAE

*Hypopterygium japonicum* Mitt. in Journ. Linn. Soc. 1864; 155 (1864). (*H. canadense* Kindb.) Aats Bay (926, 962); Egg Harbor (867). This species was first found in Alaska by this expedition, and permission for advance publication granted to J. M. Holzinger (1914).

#### LESKEACEAE

*Heterocladium macounii* Best. Juneau (Mehner in 1904). New to Alaska. Previously known from Vancouver Island.

*Heterocladium heteropteroides* Best. Augustine Bay (550, 557, 676); Brownson Bay (465, 489); St. John Harbor (229); Saletry Cove (324); Swifts Cannery (685, 721).—Range, J.

*Leskea wollei* Aust. (*L. cryptophylla* Kindb.) St. Paul Island (Kincaid in 1899). New to Alaska.

*Pseudoleskea atrovirens* (Dicks.) B. S. G. Juneau (Mehner in 1904).—Range, Y. J.

This was known from Alaska only from Yakutat Bay (Cardot & Theriot, 1902).

*Cladopodium bolanderi* Best. (*Thuidium bolanderi* Kindb.) Juneau (Mehner in 1904).—Range, P. J.

*Cladopodium crispifolium* (Hook.) Ren. & Card. (*Hypnum crispifolium* Hook.; *Thuidium crispifolium* Kindb.) Aats Bay (858, 915); Brownson Bay (507); Hidden Inlet (83); St. John Harbor (219); Swifts Cannery (707).—Range, P. J.

*Cladopodium pellucinerce* (Mitt.) Best. Juneau (Mehner in 1905).—Range, J.

Williams (1901) found this in the region at the head of Lynn Canal.

*Helodium paludosum* (Sull.) Aust. (*Thuidium paludosum* Rau & Herv.; *Hypnum paludosum* Sull.; *Elodium paludosum* of John Macoun in 1902.) Juneau (Mehner in 1904). New to Alaska.

#### BRACHYTHECIACEAE

*Camptothecium lutescens* (Huds.) B. S. G. (*Hypnum lutescens* Huds.) Aats Bay (920); Alimvoak Bay (1273).—Range, N. B. P. J.

*Camptothecium paulianum* A. J. Grout, n. sp. Robust, bright yellowish-green. Apparently growing in a deep mass with erect stems. Stems 6-10 cm. long, irregularly subpinnately branching. Leaves strongly secund, giving the plant the appearance of a *Drepanocladus*.

Stem leaves lanceolate to ovate-lanceolate, reaching 4 mm. or more in length, not decurrent, costate to the base of the very long filiform acumens, nearly or quite entire, very strongly sulcate and plicate; leaf cells very long and narrow, the walls nearly half as thick as the width of the lumen; alar cells broader and shorter, oblong to subquadrate; branch leaves similar, but often serrulate. Perichaetial leaves lanceolate, reaching 6 mm. in length, long filiform-acuminate, serrulate above. Sporophyte reaching 4 cm. in length; seta smooth; capsule oblong-cylindric, somewhat curved and cernuous, about 3 mm. long; operculum conic-apiculate; peristome immature but apparently perfect. Associated with *Tortula ruralis*.

St. Paul Island (Kincaid in 1899). Type in herbarium of A. J. Grout. (Grout).

*Brachythecium albicans* (Neck.) B. S. G. Alimvoak Bay (1275); Swifts Cannery (781); Tanana (O. Clark in 1911); Wrangell (1170, Engstrom in 1905).—Range, B. A. P. Y. J.

*Brachythecium asperrimum* (Mitt.) Kindb. Tanana (O. Clark in 1910).—Range, T. J.

This was known from Alaska only from Cape Fox (Cardot & Theriot, 1902).

*Brachythecium compestre* (Bruch) B. S. G. Juneau (Mehner in 1904). New to Alaska.

*Brachythecium lamprochryseum* C. Muell. & Kindb. Alimvoak Bay (1317); Calder (865); Juneau (Mehner in 1904); Ketchikan (513); Lazy Bay (1274); Stepovak Bay (1313); Swifts Cannery (755).—Range, A. P. J.

It was known from Alaska only from Unalaska (Cardot & Theriot, 1906).

*Brachythecium mildeanum* Schimp. (*B. acutum* Sull.) Juneau Mehner in 1904). New to Alaska.

*Brachythecium oxycladon* (Brid.) Jaeg. Ketchikan (19). New to Alaska.

*Brachythecium pacificum* (Ren. & Card.) Grout in Herb. (Feb. 1919).\* (*B. reflexum pacificum* Ren. & Card. in Bot. Centralb., 1890, No. 51; *Eurhynchium pacificum* Kindb. in Eur. and N. Amer. Bryineae, p. 101, 1896.) Juneau (Mehner in 1904).—Range, Y. J.

These plants are glossy, pale greenish-yellow. There are several fruits, showing the seta quite rough throughout its length, the capsule short, at right angles to the seta, and curved. No operculum.

In a note Cardot & Theriot (1902, p. 335) give several characters

\*In Barnes' Key to North American Mosses, *Brachythecium reflexum pacificum* Ren. & Card. is said to be described in "Hedwigia 32: 262, 1893." But the first description is evidently in Bot. Centralb., 1890, No. 51.

of this Alaskan plant which to them seem constant, leading them to the suggestion that "perhaps Mr. Kindberg is right in considering this moss a species distinct from *Brachythecium reflexum*." Dr. Grout also noted that the plant is "surely distinct from *Brachythecium reflexum*."

In Holzinger's herbarium there lies a plant from Tromsø, Norway, collected by J. E. Zetterstedt, under the name of *Brachythecium reflexum* B. S., which agrees perfectly with this Alaska plant, in the pale glossy color, shape and aerolation of leaves and leaf angles, and costa. The leaf margin in the Norwegian plant is a trifle more distinctly serrate. Also the plant is a trifle smaller.

Neither of these two plants is correctly figured in plate 539 of *Bryologia Europea*: in that plate the leaf margin is too distinctly serrate, the leaf cells are too short by half, the costa is too heavy. The form of the leaf also is different. This moss thus appears to occur in Norway, but until it was found in Alaska it was not recognized as a species distinct from *Brachythecium reflexum*. (Holzinger).

*Brachythecium plumosum* (Swartz) B. S. G. Coal Harbor (Kincaid in 1899); Snug Harbor (1316).—Range, P. S.

This was known from Alaska only from Kodiak (Cardot & Theriot, 1902).

*Brachythecium pseudocollinum* Kindb. in Macoun's Cat. Canadian Plants, p. 196. 1892. Tanana (O. Clark in 1911). New to Alaska.

*Brachythecium rivulare* (Bruch) B. S. G. Juneau (Mehner in 1904); Kodiak (Mylroie in 1911); Shipley Bay (770). The material from Shipley Bay is a variety.—Range, N. B. S. Y. J.

*Brachythecium washingtonianum* Eaton. Ketchikan (O. Clark in 1910 or 1911); Shipley Bay (772). New to Alaska. The Ketchikan plant is not typical.

*Scleropodium obtusifolium* (Drumm.) Ren. & Card. Ketchikan (14). New to Alaska.

*Eurhynchium boscii* (Schwaegr.) Jaeg. (*Cirriphyllum boscii* A. J. G.) Aats Bay (922). New to Alaska.

*Eurhynchium oreganum* Sull. Augustine Bay (576, 673); Brownson Bay (487); Calder (860); Egg Harbor (853); Hidden Inlet (61); Lewis Island, B. C. (1179); Nichols Bay (404); Port San Antonio (615); Swifts Cannery (709); Tam Gas Harbor (123).—Range, J.

*Eurhynchium praelongum* (L.) B. S. G. Augustine Bay (433, 674); Egg Harbor (940); Exchange Cove (268); Lewis Island, B. C. (1180); Port San Antonio (643); Swifts Cannery (753). New to Alaska.

*Eurhynchium praelongum stokesii* (Turn.) Brid. (*E. stokesii* B. S. G.; *Hypnum stokesii* Turn.) Swifts Cannery (715).—Range, J.

*Eurhynchium stoloniferum* (Hook.) Jaeg. & Sauerb. (*Hypnum stoloniferum* Hook.; *Scleropodium stoloniferum* Brid.) Aats Bay (909); Augustine Bay (562); Egg Harbor (850); Exchange Cove (270, 273); Hidden Inlet (62, 87); Juneau (Mehner in 1904); Ketchikan (16); Lake Bay (198); Lewis Island, B. C. (1182); Metlakatla (98); Morse Cove (447, 448); Nichols Bay (382); Port Malmsbury (985, 988); Port San Antonio (602, 612); St. John Harbor (238); Saltery Cove (322); Shipley Bay (1181, 1183); Sitklan Island (45); Swifts Cannery (701, 702, 753); Tam Gas Harbor (129).—Range, J.

*Eurhynchium strigosum* (Hoffm.) B. S. G. (*Hypnum strigosum* Hoffm.) Tanana (O. Clark in 1911).—Range, N. T.

*Eurhynchium strigosum fallax* Rend. & Card. (*E. fallax* Grout.) Seldovia (unnumbered).—Range, A. S. J.

#### HYPNACEAE

\* *Plagiothecium denticulatum* (L.) B. S. G. (*Hypnum denticulatum* L.) Ketchikan (501); St. John Harbor (235); Wrangell (Engstrom in 1905).—Range, P. S. Y. J.

*Plagiothecium deplanatum* (Schimp.) Grout. (*Hypnum deplanatum* Schimp.; *Rhynchostegium deplanatum* Schimp.) Verdure Creek (28). New to Alaska.

*Plagiothecium elegans* (Hook.) Sull. Egg Harbor (942); Port San Antonio (598); Swifts Cannery (714); Turner River (1030).—Range, J.

*Plagiothecium fallax* Card. & Ther. in Proc. Wash. Acad. Sci. 4: 336. 1902. Juneau (Mehner in 1904).—Range, J.

*Plagiothecium piliferum* (Swartz) B. S. G. (*P. trichophorum* Lesq. & James). Juneau (Mehner in 1904).—Range, J.

*Plagiothecium striatellum* (Brid.) Lindb. Baranof (1092); Egg Harbor (849); Juneau (Mehner in 1904); Ketchikan (510). New to Alaska.

*Plagiothecium silvaticum* B. S. G. Juneau (Mehner in 1904).—Range, P. J.

*Plagiothecium undulatum* (L.) B. S. G. (*Hypnum undulatum* L.) Aats Bay (936); Augustine Bay (552); Baranof (1083); Juneau (Mehner in 1904); Kodiak (Mylroie in 1911); Lake Bay (214); Lewis Island, B. C. (1176); Morse Cove (450); Port Alice (782); Port Chatham (1236); Port Malmsbury (1001); Port San Antonio (621, 1173); Ratz Harbor (299); Shell Island, B. C. (1177); Ship-

ley Bay (1178); Shuyak Island (1262); Sitklan Island (46); Swifts Cannery (694); Tam Gas Harbor (131).—Range, P. S. J.

*Amblystegium compactum* (C. Muell.) Aust. St. Paul Island (Kincaid in 1899). New to Alaska. Williams (1901) found it in the Dawson region of Yukon.

*Amblystegium filicinum* (L.) De Not. Juneau (Mehner in 1904). New to Alaska. Williams (1901) found this species in southern Yukon.

*Chrysohypnum section of Hypnum.*

*Hypnum treleasei* Ren. in Proc. Wash. Acad. Sci. 4: 298. 1902. Juneau (Mehner in 1904).—Range, B. S. J.

*Drepanocladus section of Hypnum.*

*Hypnum fluitans* (Dill.) L. Brownson Bay (509); Cape Douglas (1235); Morse Cove (464).—Range, P. Y. J.

*Hypnum fluitans purpurascens* Schimp. (*H. purpurascens* Limpr.; *H. exannulatum purpurascens* Milde). St. John Harbor (259). New to Alaska.

*Hypnum fluitans falcifolium* Ren. Brownson Bay (509); Lazy Bay (1238). New to Alaska.

*Hypnum fluitans falcatum* B. S. G. Cape Douglas (1331, 1332, 1333).—Range, B. P.

This was reported by Cardot & Theriot (1906) from St. Michael and Cape Nome.

*Hypnum revolvens* Swartz. Juneau (Mehner in 1905).—Range, N. P. B. J.

*Hypnum uncinatum* Hedw. Aats Bay (919); Juneau (Shumway in 1891, Mehner in 1904); Kodiak (Mylroie in 1911); Port Malmsbury (995); Seward (1240); Tanana (O. Clark in 1911).—Range, N. T. B. P. S. J.

*Hypnum uncinatum plumosum* Schimp. Tanana (O. Clark in 1911). New to Alaska.

*Hypnum vernicosum* Lindb. Cape Douglas (1242). New to Alaska.

*Cratoneuron section of Hypnum.*

*Hypnum commutatum* Hedw. Juneau (Mehner in 1904). New to Alaska.

*Ptilium section of Hypnum.*

*Hypnum cristacastrensis* L. Baranof (1077); Juneau (Mehner in 1904 and 1905); Tanana (O. Clark in 1911); Wrangell (Foster in 1913).—Range, T. B. P. S. J.

*Stereodon section of Hypnum.*

*Hypnum callichroum* (Brid.) B. S. G. Baranof (1078); Juneau (Mehner in 1904); Kodiak (Mylroie in 1911).—Range, P. S. Y. J.

*Hypnum canadense* Kindb. Augustine Bay (558, 563, 680); Hidden Inlet (91); Port Alice (726); Port Chatham (1236, 1237); St. John Harbor (226).—Range, S. J.

*Hypnum circinale* Hook. Hidden Inlet (68); Juneau (Mehner in 1904); Kodiak (Mylroie in 1910); Lake Bay (196, 215); Lewis Island, B. C. (1173); Morse Cove (460); Port San Antonio (1172); Sitklan Island (49); Swifts Cannery (713); Tam Gas Harbor (126).—Range, N. T. P. S. Y. J.

*Hypnum dieckii* Ren. & Card. Juneau (Mehner in 1905); Port Chatham (1330).—Range, A. S. J.

*Hypnum subimponens* Lesq. Aats Bay (851); Nichols Bay (397); Wrangell (1169).—Range, J.

*Hygrohypnum section of Hypnum.*

*Hypnum eugyrium* (B. S. G.) Schimp. Ketchikan (7). New to Alaska.

*Hypnum ochraceum* Turn. Alimvoak Bay (1317 in part); Juneau (Mehner in 1904); Port Alice (727).—Range, P. Y. J.

*Hypnum pseudomontanum* Kindb. Calder (828).—Range, S. J.

This was known from Alaska only from Port Etches on Prince William Sound (John Macoun, 1902).

*Calliergon section of Hypnum.*

*Hypnum sarmentosum* Wahl. Alimvoak Bay (1239).—Range, P. S.

*Hypnum schreberi* Willd. (*Hylocomium schreberi* De-Not.; *Hylacomium parietinum* Lindb.) Baranof (1098); Brownson Bay (493); Metlakatla (101); Nichols Bay (389); Turner River (1087); Wrangell (1168).—Range, B. P. S. J.

*Hypnum stramineum* Dicks. Baranof (1086); Turner River (1032).—Range, A. B. J.

*Hypnum tananae* Grout, n. sp. (*Calliergon tananae* Grout in Herb.)

Stems very slender and subpinnately branching, 20-25 cm. long, red as in *H. schreberi*, but leaves of stem and branches often closely appressed, giving the whole plant a filiform appearance like some slender form of *H. cuspidatum*. Stem leaves about  $1\frac{1}{2}$  mm. long, broadly ovate, slightly concave, rounded and broadly obtuse at apex, conspicuously narrowed to the slightly decurrent insertion, entire or

very minutely denticulate at apex; costa short and double or almost lacking, faint; median leaf cells very long and narrow; basal shorter and broader; alar somewhat inflated and colored; branch leaves smaller. Sporophyte unknown. The general outline of the leaves is short, little concave, as in small forms of *H. schreberi*; but the alar cells are more inflated. The plants of the type were mixed with *H. uncinatum*.

Tanana (O. Clark in 1911). Type in Herb. of A. J. Grout.

*Hylocomium loreum* (L.) B. S. G. (*Hypnum loreum* L.). Augustine Bay (554); Baranof (1082, 1093, 1107); Brownson Bay (477); Calder (836); Cape Douglas (1258); Hidden Inlet (64); Hoodoo Islands (Birkett in 1907); Juneau (Mehner in 1904); Ketchikan (13); Lake Bay (216); Lewis Island, B. C. (1115); Long Island (1334); Metlakatla (112); Mitrofanina Bay (1257, 1260); Morse Cove (456); Nichols Bay (400); Northwest Harbor (1256); Port Chatham (1261); Port Malmsbury (1003); Port San Antonio (651, 1114); Ratz Harbor (302); Saltery Cove (330); Shipley Bay (764); Snug Harbor (1259); Swanson Bay, B. C. (1116); Swift Cannery (719); Turner River (1033); Verdure Creek (24).—Range, P. S. Y. J.

*Hylocomium splendens* (Hedw.) B. S. G. (*H. proliferum* Lindb.; *Hypnum splendens* Hedw.). Aats Bay (914); Augustine Bay (565); Baranof (1091); Farragut Bay (Kincaid in 1899); Hidden Inlet (71); Juneau (Mehner in 1904); Kodiak (Myloie in 1910); Lake Bay (1113); Lewis Island (1112); Mitrofanina Bay (1254, 1255); Morse Cove (451); Northwest Harbor (1252); Saltery Cove (329); Seward (1253); Swanson Bay, B. C. (1111); Swifts Cannery (717); Tam Gas Harbor (152); Tanana (O. Clark in 1911); Verdure Creek (38).—Range, T. B. A. P. S. Y. J.

*Hylocomium splendens gracilius* Boul. (*H. alaskanum* Kindb.; *Pleurozium alaskana* James). Kodiak (Myloie in 1911); Tanana (O. Clark in 1911).—Range, T. B. A. J.

There seems to be no doubt about referring these here. The remarks on this variety by Cardot & Theriot (1902) apply, except that not all the leaves are apiculate. It appears to be a depauperate form of *H. splendens*, into which it grades. All sterile.

*Hylocomium squarrosus* (L.) B. S. G. (*Hypnum squarrosus* L.). Izhut Bay (1249); Juneau (Mehner in 1904); Lake Bay (199); Long Island (1248, 1329); St. Paul Island (Kincaid in 1899); Shipley Bay (769); Snug Harbor (1247, 1251); Swanson Bay, B. C. (1171); Swifts Cannery (757); Yakutat Bay (1250).—Range, B. A. P. Y. J.



*Hylocomium triquetrum* (L.) B. S. G. (*Hypnum triquetrum* L.) Aats Bay (913); Alimvoak Bay (1278 in part); Baranof (1096); Deweyville (793, 794); Hidden Inlet (85); Juneau (Mehner in 1904; Kodiak (Mylorie in 1910 and 1911); Long Island (1246); Mitrofan Bay (1243, 1245); Tam Gas Harbor (140); Tanana (O. Clark in 1910). --Range, T. B. P. Y. J.

The total number of species listed in this paper is 198, with 25 varieties in addition. Two new species appear, *Camptothecium paulianum* and *Hypnum tananae*; one new variety, *Aulacomnium androgynum pygmaeum*; and one new combination, *Brachythecium pacificum*. At least two species known from other regions are here recorded for the first time as occurring in North America, *Geheebia gigantea* and *Zygodon reinwardti*. Including the foregoing, the total number of species not before reported from Alaska, is 44, and the total number of varieties so reported is 11. The reestablishment of the genera *Geheebia* and *Trachycystis* is suggested.

Dr. John W. Bailey named a large number of the mosses, both acrocarpous and plurocarpous. Dr. A. L. Andrews named most of the Bryums. Dr. A. J. Grout named the Brachytheciaceae for the most part, and also some related species. Mr. E. B. Chamberlain made all the drawings and helped in other ways. Mr. R. S. Williams assisted in the determination of certain difficult species. We here express our appreciation for all this assistance. The remaining mosses fell about equally to the two writers. Frye is responsible for errors outside the list of species.

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# PUBLICATIONS PUGET SOUND BIOLOGICAL STATION

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### **Announcement**

The *Publications Puget Sound Biological Station* of the University of Washington appear at irregular intervals. The articles are numbered consecutively from the beginning of the Publications. The pages and plates are consecutive throughout a volume. The subscription price is \$3.50 per volume of about 400 pages. For information address Dr. T. C. Frye, University of Washington, Seattle, Washington.

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## Revised Key to the Echinoderms of Friday Harbor

MILDRED BUSH

*Puget Sound Biological Station, Friday Harbor, Washington*

This paper is intended to correct certain errors and to bring up to date the key published several years ago.<sup>1</sup> The descriptions are here omitted in so far as they did not need recasting. It is expected that this key will be used in conjunction with the previous article to which reference is made. The same plates are used in this paper.

- A. With rays.
    - B. Rays grading into the disk; with ambulacral groove containing tube feet ASTEROIDEA (p. 65)
    - BB. Rays sharply differentiated from the disk; without ambulacral groove and tube feet. OPHIUROIDEA (p. 70)
  - AA. Without rays.
    - C. With hard calcareous shell. ECHINOIDEA (p. 72)
    - CC. Without hard calcareous shell. HOLOTHUROIDEA (p. 73)
- ASTEROIDEA
- A. Ambulacral feet usually in 4 rows; pedicellariae either forceps-like or shears-like.
    - B. Rays 5, or rarely 6.
      - C. Dorsal spines either forming a network or clustered.
        - D. Interactinal spines in 3 or 5 or more rows.
          - E. Adambulacral spines 1 to a plate, in 1 row. PISASTER (p. 68)
          - EE. Adambulacral spines alternately 1 and 2 to a plate. EVASTERIAS (p. 69)
        - DD. Interactinal spines usually in 1 row with 1 or 2 short rows near the disk. ASTERIAS VICTORIANA (Fig. 21)
      - CC. Dorsal spines in 3 to 7 rather regular rows. ORTHASTERIAS (p. 69)
    - BB. Rays 6, or rarely 5. LEPTASTERIAS (p. 69)
    - BBB. Rays 20 to 24. PYCNOPODIA HELIANTHOIDES (Fig. 26)
  - AA. Ambulacral feet in 2 rows; pedicellariae not as above.
    - F. Margin of animal never rigid; marginal plates of the rays small, sometimes indistinct.
    - G. Surface rough, calcareous; spine-clusters on raised ossicles, not fan-shaped.
    - H. Rays somewhat terete, long; disk small. HENRICIA LEVIUSCULA<sup>2</sup> (Fig. 7)
    - HH. Rays somewhat flattened, medium in length; disk broad.

<sup>1</sup> Bush, M. Key to the Echinoderms of Friday Harbor, Washington. Publ. Puget Sound Biol. Sta. 2: 17-44. 1918.

<sup>2</sup> Verrill recognizes a variety *lunula*. It differs from the type in having the ossicles reniform curved, or crescentic with blunt tips. It is common in deep water in our region.

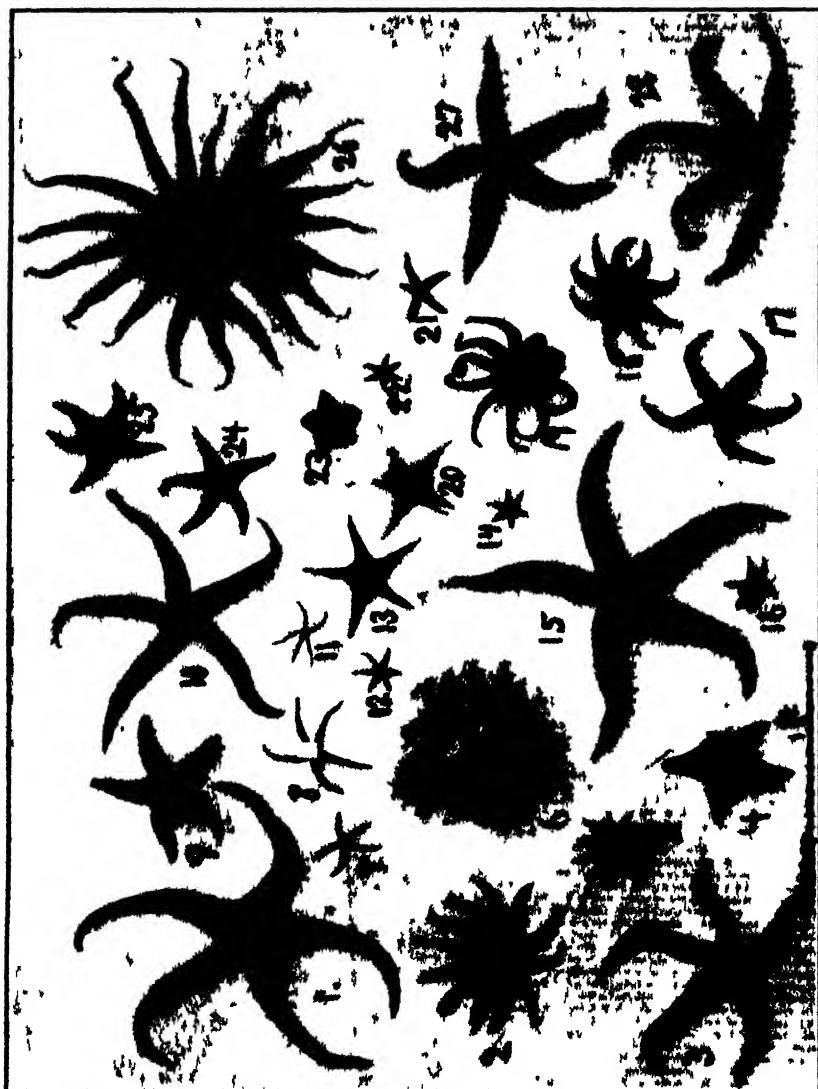


PLATE 9

## PLATE 9

- Fig. 1. *Pisaster papulosus* Ver.  
 Fig. 2. *Solaster dawsoni* Ver.  
 Fig. 3. *Evasterias acanthostoma* Ver.  
 Fig. 4. *Dermasterias imbricata* (Grube) Per.  
 Fig. 5. *Crossaster popposus* (L.) M. & T.  
 Fig. 6. *Gorgonocephalus eucnemis* M. & T.  
 Fig. 7. *Henricia leviuscula* (Stim.) Fish.  
 Fig. 8. *Henricia leviuscula lunula* Ver.  
 Fig. 9. *Pisaster ochraceus* (Brandt) A. Ag.  
 Fig. 10. *Luidia foliolata* Grube.  
 Fig. 11. *Ophiura lütkenii* (Lym.) Meiss.  
 Fig. 12. *Leptasterias aequalis* (Stim.) Ver.  
 Fig. 13. *Mediaster aequalis* Stim.  
 Fig. 14. *Leptasterias epichlora alaskensis* Ver.  
 Fig. 15. *Evasterias troschelii rudis* Ver.  
 Fig. 16. *Leptasterias heractis* (Stim.) Ver.  
 Fig. 17. Hybrid of *Evasterias* species.  
 Fig. 18. *Solaster galaxides* Ver.  
 Fig. 19. *Solaster stimpsoni* Ver.  
 Fig. 20. *Medaster aequalis* Stim.  
 Fig. 21. *Asterias victoriana* Ver.  
 Fig. 22. *Leptasterias aequalis* (Stim.) Ver.  
 Fig. 23. *Pisaster tessellatus* Ives.  
 Fig. 24. *Pisaster confertus* (Stim.) Ver.  
 Fig. 25. *Pisaster ochraceus* (Brandt) A. Ag.  
 Fig. 26. *Pycnopodia helianthoides* (Brandt) Stim.  
 Fig. 27. *Evasterias troschelii* (Stim.) Ver.  
 Fig. 28. Hybrid of *Evasterias troschelii rudis* Ver. and  
*E. troschelii subnodosa* Ver.

- I. Dorsal spines equal in length, short, blunt; spine-bearing ossicles crowded. SOLASTER (p. 70)
- II. Dorsal spines unequal in length, long, slender; spine-bearing ossicles scattered. CROSSASTER PAPPOSUS (Fig. 5)
- GG. Surface slippery; spine-clusters not on raised ossicles, fan-shaped. PTERASTER TESSELATEDUS (Fig. 23)
- FF. Margin of animal rigid; marginal plates or rays large.
- J. Surface rough.
- K. Disk large; rays short. (Figs. 13, 20).
- L. Inflated, large. GEPHYREASTER (p. 70)
- LL. Flattened, medium in size.
- M. Rays shorter than the disk is broad.
- MM. Rays as long as the disk is broad.
- KK. Disk small; rays long.
- JJ. Surface smooth.
- CERAMASTER GRANULARIS Verrill
- MEDIASTER AEQUALIS (Figs. 13, 20)
- LUIDIA FOLIOLATA (Fig. 10)
- DERMASTERIAS IMBRICATA (Fig. 4)
- Pisaster*

- A. Large, up to 75 cm. or more. 1. *P. papulosus*
- AA. Medium, rarely over 25 cm.
- B. Dorsal spines unequal, large, strongly capitate. 2. *P. ochraceus*
- BB. Dorsal spines equal, small, not strongly capitate. 3. *P. confertus*
1. *Pisaster papulosus* Verrill.
- Very large, (Fig. 1), 75 centimeters or more in diameter, lavender

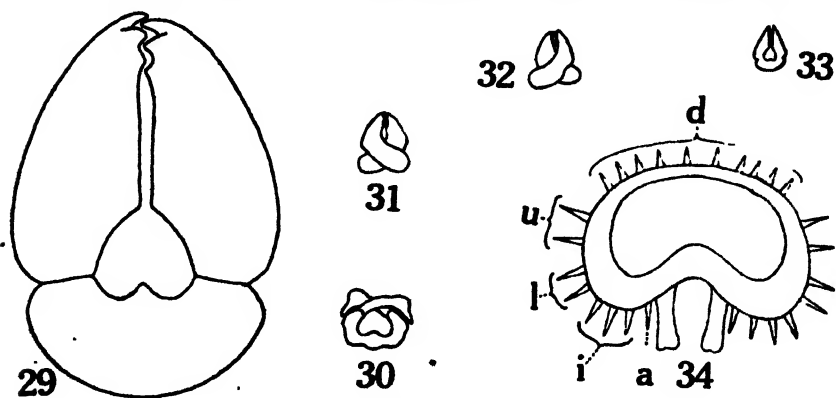


PLATE 10

- Fig. 29. Major pedicellaria of *Pisaster ochraceus*.  $\times 36$ .
- Fig. 30. Minor pedicellaria of *Pisaster papulosus*.  $\times 36$ .
- Fig. 31. Minor pedicellaria of *Pisaster ochraceus*.  $\times 36$ .
- Fig. 32. Minor pedicellaria of *Pisaster papulosus*.  $\times 36$ .
- Fig. 33. Small major pedicellaria of *Pisaster papulosus*.  $\times 36$ .
- Fig. 34. Diagram showing the groups of spines used in classification: (d) dorsal region; (u) upper marginal region; (l) lower marginal region; (i) interradial region; (a) ambulacral region.  $\times 36$ .

in color. Dorsal spines long, large, sometimes clustered but usually in medial radial rows with open network on each side of the rows; papular areas large. Upper marginal spines large, long, somewhat flattened or gouge-shaped, forming a distinct and usually double row. Ambulacral spines and plates crowded, the spines slender. Major pedicellariae numerous, some very large and scattered irregularly over the surface, others as small as the minor pedicellariae and clustered (Fig. 33). Minor pedicellariae abundant, some of the ordinary forceps kind (Fig. 32), others widely arched and in profile resembling hooks (Fig. 30). Dorsal minor pedicellariae in large groups on the dermis and around the bases of the spines. In deep water; not numerous.

2. *Pisaster ochraceus*<sup>a</sup> (Brandt) A. Agassiz. (*Asterias ochraceus* Brandt; *Asterias janthine* Brandt; *Asteracanthion margaritifer* Müller & Troschel).

Medium sized (Fig. 25). Dorsal spines coarse, stout, strongly capitate, very unequal, in a netlike arrangement with large meshes, sometimes with wide papular areas, sometimes in partial median rows, sometimes with groups where the lines intersect.—Along the tide line; abundant.

3. *Pisaster confertus* (Stimpson) Verrill.

Medium sized (Fig. 24). Dorsal spines small, numerous, not strongly capitate, acute or clavate, arrangement a fine meshed net, with or without median rows, without noticeable groups, with or without central pentagon.—Along the tide line; abundant.

#### *Evasterias*

- A. Dorsal spine arrangement net-like or clusters; interactinal spines in 4 to 6 rows. *EVASTERIAS TROSCHELII*<sup>4</sup> (Fig. 27)

- AA. Dorsal spine arrangement not net-like but often transverse rows; interactinal spines in more than 6 rows.

*EVASTERIAS ACANTHOSTOMA* (Fig. 3)

#### *Orthasterias*

- A. Dorsal spines in 5 or more indistinct radial rows.

*ORTHASTERIAS COLUMBIANA* Verrill

- AA. Dorsal spines in 1 to 3 radial rows with others scattered or reticulate.

*ORTHASTERIAS FORRERI*<sup>5</sup> Verrill

#### *Leptasterias*

- A. Dorsal spines equal, in 5 to 7 rows on each ray.

- B. Surface even; spines not capitate.

*LEPTASTERIAS AEQUALIS* (Fig. 22)

<sup>a</sup> A variety *nodulosus* is sometimes recognized. It is usually somewhat smaller than the type and has the dorsal spines conspicuously clustered. It occurs along the tide line, but is not abundant.

<sup>4</sup> Three varieties which have been recognized by Verrill have been found at Friday Harbor. (Bush, M. Publ. Puget Sound Biol. Sta. 2: 17-44. 1918.)

<sup>5</sup> A variety *foretipulata* has been recognized by Verrill, and occurs at Friday Harbor. It is distinguished from the type in having the dorsal spines in one median row, and in having some of the minor pedicellariae hook-like.



AA. Dorsal spines unequal, not in rows or only in a median radial one.  
LEPTASTERIAS EPICHLORA<sup>o</sup> Verrill

BB. Surface uneven; spines capitate.

LEPTASTERIAS HEXACTIS (Fig. 16)

*Solaster*

A. Rays 9 or 10.

B. Rays short, flattened

SOLASTER GALAXIDES (Fig. 18)

BB. Rays long, almost terete.

SOLASTER STIMPSONI (Fig. 19)

AA. Rays 12 or 13.

SOLASTER DAWSONI (Fig. 2)

*Gephyreaster*

Large, robust, inflated; disk broad; rays short, broad at base, tapering evenly; surface covered with large paxillae which are covered with granules.

1. *Gephyreaster swifti* Fisher. (*Mimaster swifti* Fisher).

Coral in color; disk broad, thick; dorsal surface arched on rays and disk, covered with paxillae; paxillae broad, flat, close together, in rows near base of rays but without order on distal portion, covered with thimble-shaped or acorn-shaped granules 20 to 40 to a plate. Marginal plates conspicuous, resembling large paxillae; upper and lower margins separated by a groove, covered with granules which increase in size toward the oral side; ambulacral plates wider than long, densely covered with spines; mouth plates large.—In deep water; not numerous.

OPHIUROIDEA

A. Rays unbranched; lateral plates of the rays spine-bearing; ambulacral ossicles articulating by means of processes and pits.

B. Tentacle scales on basal joints of rays several to each pore.

OPHIURA (p. 70)

BB. Tentacle scales not more than 2 to each pore.

C. Median dorsal plates of the rays surrounded by a series of smaller plates; upper ray plates with supplementary plates.

OPHIOPHOLIS (p. 71)

CC. Median dorsal plates of the rays not surrounded by a series of smaller plates; upper ray-plates with no supplementary plates.

D. Oral papillae subequal, in a regular series.

AMPHIODIA (p. 71)

DD. Oral papillae unequal, the outer as long as the sum of the inner two.

AMPHIOPHOLIS (p. 72)

AA. Rays unbranched in ours; lateral plates of the rays not spine-bearing; ambulacral plates articulating by means of hour-glass-shaped surfaces.

GORGONOCEPHALUS EUCNEMIS (Fig. 6).

*Ophiura*

A. Comb at base of each ray on upper side composed of broadly truncate closely crowded papillae.

1. *O. lütkenii*

<sup>o</sup> Verrill has recognized a variety *alaskensis* which differs from the type in having 6 rays. It occurs along the tide line in the Friday Harbor region, but is not numerous.

AA. Comb at base of each ray made up of blunt well spaced papillae.

2. *O. sarsii*

1. *Ophiura lütkenii* (Lyman) Meissner.

Color various, usually gray or brown. Disk 10 to 25 mm. across, pentagonal, not thicker than the rays; rays 5, long, slender, from the corners of the disk-pentagon, limited in movement; spines on disk none; plates on upper and lower sides of disk resembling fish scales; scales small except the radial shields; mouth-shields large; side ray-plates well developed, bearing 3 graded spines, the uppermost of these spines longest and all parallel to the axis of the rays; oral papillae many.—In deep water; numerous. (Fig. 11).

2. *Ophiura sarsii* Lütken.

This species is similar to the preceding one and is found in similar places, but it is easily distinguished by the difference in the ray-combs.—In moderately deep water, on fine sandy bottom.

#### *Ophiopholis*

1. *Ophiopholis aculeata* (Retzius) Gray.

Usually red. Rays 5, moderately long, somewhat flattened, movement limited. Disk 10 to 20 mm. across, covered with small conical spinelets and a series of 3 to 5 rounded plates from the base of each ray almost to the center, 5-lobed; disk-lobes alternating with the rays, showing conspicuously on the lower side. Plates of rays well developed, the lateral plates each bearing 5 spines on each side; these spines varying in length, the middle one the longest.—In deep water, often on the holdfasts of kelp (*Nereocystis*); rather numerous.

#### *Amphiodia*

A. Arm-spines thick and very blunt.

1. *A. occidentalis*

AA. Arm-spines thin, flat, sharp-pointed.

2. *A. peloria*

1. *Amphiodia occidentalis* (Lyman) Verrill.

Disk usually gray; rays white. Disk 5 to 12 mm. across, delicate, rather thick, not deeply lobed; lobes alternating with the rays; spines none; surface covered with overlapping plates; plates rather small except those nearest the radial shields; large, longer than broad, not closely joined. Rays slender, long, 12 to 15 times the diameter of the disk, originating from shallow grooves on the under side of the disk; movements in a vertical plane and toward the mouth; dorsal plates of rays not surrounded by smaller plates; lateral plates each bearing 3 equal spines forming longitudinal rows along the sides.—In mud at low tide; not numerous.

2. *Amphiodia peloria* sp. nov. (Greek *pelorios*; huge, immense).

Disk gray or reddish, mottled with blackish (strongly yellow in dry specimen); rays usually reddish, with lateral portions of upper ray-

plates dusky, and ray-spines pale yellow. Disk about 20 mm. across, covered with rather coarse scales; scales larger near the radial shields, smallest near the margin in the interradii; interradii areas orally covered with innumerable minute scales; oral shields nearly circular though the distal side may project a trifle, about 0.7 to 0.8 mm. in diameter; adoral plates small, widest at outer ends, scarcely meeting radially; oral papillae 3, subequal but the outermost somewhat more pointed than the others. Rays about 350 mm. long; radial shields rather small, scarcely 3 mm. long by 1.5 mm. wide, in contact at their outer ends but separated within by 5 or 6 large scales; upper ray-plates quadrilateral and nearly rectangular, about a half mm. wide, their margins nearly parallel; ray-plates 3, subequal, 0.6 to 0.7 mm. long, flat and sharply pointed, appressed to the side of the arm; under ray-plates quadrilateral, generally wider than long, their distal margin more or less concave, their lateral and proximal margins more or less convex especially near the base of the ray, their margins more nearly straight and parallel near the middle of the ray; tentacles and tentacle pores very large; tentacle scales 2, but on the proximal half of the ray widely separated from each other since the one attached to the side ray-plate is placed very near the base of the lowest ray-spine.

Holotype; Museum Comparative Zoology of Harvard University, No. 4448. Washington, Puget Sound, Olga; buried about 15 inches in sand, with tips of the rays projecting. Dean C. Engberg of the University of Nebraska, collector.

This remarkable species is probably the largest of the genus. It is nearly related to both *A. periercta* Clark, with which it was first identified (1918, Publ. Puget Sound Biol. Sta., Vol. 2, p. 34) and *A. occidentalis* Verrill, but it is easily distinguished from either by the flat, pointed ray-spines and the excessively long rays. The oral and the radial shields also seem to be quite characteristic. The species is erected at the suggestion of Dr. H. L. Clark of Harvard.

#### *Amphiopholis*

##### 1. *Amphiopholis pugetana* (Lyman) Verrill.

Disk small, less than 10 mm. across; rays very slender. Similar to the species of *Amphiodia* but easily distinguished by the oral papillae; the outermost papillae are so long and narrow (or short and wide, if you prefer) that they seem nearly to close the mouth slit.—Sandy bottom; Friday Harbor; Trevor Kincaid, 1907.

#### ECHINOIDEA

A. Hemispherical; anus apical.

STRONGYLOCENTROTUS (p. 73)

AA. Discoidal; anus not apical.

DENDRASTER (p. 73)

*Strongylocentrotus*

A. Color purple or red.

B. Mature tests up to 15 cm. in diameter; spines pointed at tip; genital plates larger than the radials.

STRONGYLOCENTROTUS FRANCISCANUS A. Agassiz

BB. Mature tests not over 8 cm. in diameter; larger spines truncated at tip; genital plates not larger than the radials.

STRONGYLOCENTROTUS PURPURATUS Stimpson

AA. Color greenish; tests up to 10 cm. in diameter; spines pointed at tip; genital plates larger than the radials.

STRONGYLOCENTROTUS DROBACHIENSIS A. Agassiz

*Dendraster* (Echinarachnius)

Apical system not central; divisions of dorsal star petal-like with open ends; furrows on lower side bifurcated and branched; genital pores 4, none in the posterior interradius.

1. *Dendraster excentricus* (Eschscholtz) A. Agassiz. (*Echinarachnius excentricus* Eschscholtz).

Disk somewhat straight across the posterior part; posterior ambulacral zones shorter than the other three.—In sand at False Bay; numerous.

## HOLOTHUROIDEA

A. Tube-feet present.

B. Tube-feet not confined to ventral surface but in radial rows.

CUCUMARIA (p. 73)

BB. Tube-feet confined to ventral surface.

C. Animal 45 cm. or less long; sole-like ventral surface not well developed.

STICHOPUS CALIFORNICUS H. L. Clark

CC. Animal 5 cm. or less long; sole-like ventral surface well developed.

PSOLUS CHITONOIDES H. L. Clark

AA. Tube-feet none.

D. Worm-like, semi-transparent.

E. Calcareous deposits in the form of anchors and plates, not forming dots on the skin.

LEPTOSYNAPTA INHAERENS Verrill

EE. Calcareous deposits in the form of wheels, forming dots on the skin.

CHIRIDOTA LAEVIS Fabricius

DD. Not worm-like, body tapering to a tail; opaque.

MOLPADIA (p. 76)

*Cucumaria*

A. Salmon-colored to dark purplish-red; up to 20 cm. long; tube-feet irregularly distributed in a distinct band along each radius.

1. *C. miniata*

AA. Light-colored (white, yellow, pale brown) or spotted; rarely up to 15 cm. long.

B. Light-colored, with numerous brown dots and spots; tube-feet short, in 2 simple rows on each radius.

2. *C. piperrata*

BB. Unspotted.

C. Tube-feet confined to radial series.

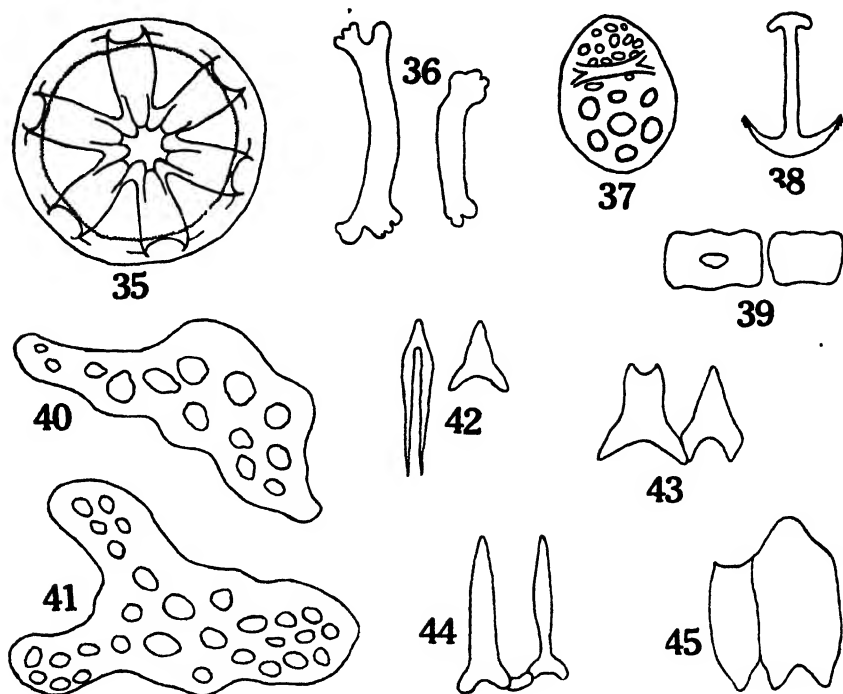


PLATE 11

- Fig. 35. Calcareous deposit from body of wall of *Chiridota laevis*.  $\times 258$ .  
 Fig. 36. Calcareous deposit from tentacle of *Chiridota laevis*.  $\times 258$ .  
 Fig. 37. Plate from body wall of *Leptosynapta inhaerens*.  $\times 258$ .  
 Fig. 38. Anchor from body wall of *Leptosynapta inhaerens*.  $\times 258$ .  
 Fig. 39. Two plates from calcareous rings of *Leptosynapta inhaerens*.  $\times 16$ .  
 Figs. 40, 41. Calcareous plates from body wall of *Cucumaria populifera*.  $\times 258$ .  
 Fig. 42. Two plates from calcareous ring of *Cucumaria populifera*.  $\times 4$ .  
 Fig. 43. Two plates from calcareous ring of *Psolus chitonoides*.  $\times 4$ .  
 Fig. 44. Two plates from calcareous ring of *Cucumaria miniata*.  $\times 4$ .  
 Fig. 45. Two plates from calcareous ring of *Molpadia intermedia*.  $\times 4$ .

D. Body blunt at each end; tube-feet very long, in 2 well marked series on each radius; usually found near tide line.

3. *C. chronhjelmi*

DD. Body pointed at each end; tube-feet short, in 2 crowded rows on each radius; usually found in deep water.

4. *C. populifera*

CC. Tube-feet scattered on interambulacra, specially on ventral surface, short.

5. *C. lubrica*

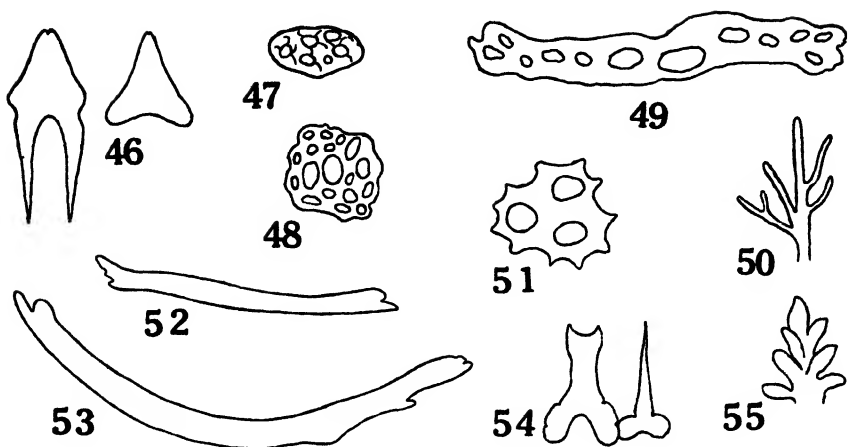


PLATE 12

Fig. 46. Two plates from calcareous ring of *Cucumaria chronhjelmi*.  $\times 4$ .

Figs. 47, 48. Calcareous deposits from body wall of *Cucumaria chronhjelmi*.  $\times 258$ .

Fig. 49. Deposit from tentacle of *Cucumaria chronhjelmi*.  $\times 258$ .

Fig. 50. Branch of respiratory tree of *Cucumaria chronhjelmi*, typical for *Cucumaria*.  $\times 12$ .

Fig. 51. Calcareous deposit from body wall of *Cucumaria piperata*.  $\times 258$ .

Figs. 52, 53. Calcareous deposits from tentacles of *Cucumaria piperata*.  $\times 258$ .

Fig. 54. Plates from calcareous ring of *Cucumaria piperata*.  $\times 4$ .

Fig. 55. Branch of respiratory tree of *Cucumaria piperata*.  $\times 12$ .

### 1. *Cucumaria miniata* (Brandt) Ludwig.

Color red-salmon to dark brownish-purple. Larger than *C. chronhjelmi*, sometimes 20 cm. long; tube-feet large, arranged in series along the radii, not in rows; tentacles 10, equal in size, much branched, rather long. Calcareous deposits not numerous, rod-like in tentacles, irregular perforated plates in the body wall; calcareous ring delicate for size of animal; radial pieces somewhat wider than the interradial, with deep notches in the posterior margin (Fig. 44).—Along shore but sometimes in deep water; numerous.

### 2. *Cucumaria piperata* (Stimpson) H. L. Clark.

Color white, with brown dots which sometimes almost cover the surface. Medium in size, 5-10 cm. long, cylindrical, blunt at both ends; surfaces smooth; tube-feet short, confined to 2 simple rows on each radius; tentacles 10, short, branched, unequal, the 4 dorsal ones the

longest. Calcareous deposits in tube-feet few, like curved rods; in body wall numerous, resembling thick knobbed plates; in the tentacles a few large supporting rods; calcareous ring small, both radial and interradiar pieces with short anterior prolongations, radial pieces notched posteriorly. Respiratory tree with short branches enlarged at tips, differing from the long finger-like branches in some other *Cucumarias* (Figs. 51-55).—In about 65 meters of water, at Olga; rather numerous.

3. *Cucumaria chrochjelmi* Theel.

White or yellowish. Medium in size, relatively slender but sometimes 15 cm. long; tube-feet very long, confined to radii, arranged in 2 rows with other feet scattered irregularly; tentacles 10, short, much branched, tuft-like, yellow. Calcareous deposits many, various in form, rod-like in tentacles, plate-like in tube-feet, basket-like or cup-like in body wall; calcareous ring large, well developed, radial pieces with rather short pointed posterior prolongations (Figs. 46-50).—Along tide line. but sometimes also in deep water; numerous.

4. *Cucumaria populifera* (Stimpson) Theel.

White or pale gray, almost transparent. Small, usually less than 5 cm. long; ends of body rather pointed, often curved upward making the ventral radii longer than the dorsal; tube-feet many, arranged in 2 crowded rows along each radius; tentacles 10, much branched, the 2 ventral ones smaller. Calcareous plates symmetrical or irregular, in crowded groups in the body wall, rod-like in tips of feet, small and irregular in tentacles; calcareous ring well developed, radial pieces with 2 long slender posterior prolongations (Figs. 40-42).—In about 65 meters of water, near Olga; numerous.

5. *Cucumaria lubrica* H. L. Clark.

Pale grayish-brown. Small, less than 5 cm. long; ends of body blunt; tube-feet short but many, mostly in double radial series which are quite distinct ventrally, less so dorsally; tentacles 10, the 4 dorsal ones largest. Calcareous particles in the body wall are chiefly thick knobbed buttons; calcareous ring small and delicate; branches of respiratory tree short, capitate.—Friday Harbor, Trevor Kincaid in 1906; 25 specimens.

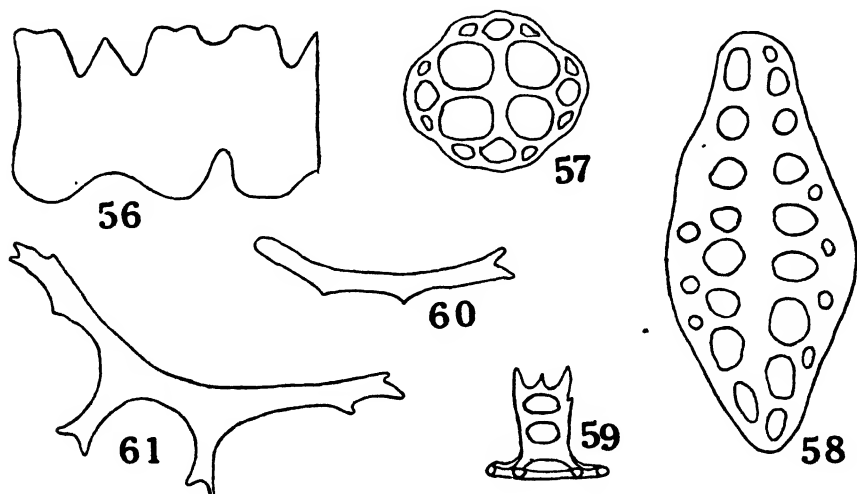
*Molpadia*

Rather stout, cylindrical, tapering to a tail; tube-feet none; tentacles 15, cylindrical with paired digits. Calcareous ring stout; radial pieces bifurcated posteriorly; calcareous and phosphatic deposits both present. Found burrowing in mud or sand, the caudal tip exposed.

1. *Molpadia intermedia* (Ludwig) H. L. Clark.

Color deep red-purple, due to the numerous phosphatic deposits.

Body stout, about 7 cm. long and 25 mm. wide; tail not abruptly narrowing, about a third the body length; tentacles 15, each with 4 sharply pointed digits. Calcareous ring stout, radial pieces with short and slightly bifurcated posterior prolongations (Fig. 45); calcareous deposits in the form of tables or enclosed cups.—In about 65 meters of water, near Olga; not numerous.



## PLATE 13

*Stichopus californicus*

Fig. 56. Plate from calcareous ring.  $\times 4$ .

Figs. 57, 58. Calcareous deposits from body wall.  $\times 258$ .

Fig. 59. Calcareous deposit from tube-foot.  $\times 258$ .

Figs. 60, 61. Calcareous deposits from tentacles.  $\times 258$ .





## **Extraction and separation of the pigments of *Nereocystis luetkeana***

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The purpose of this work was twofold: (1) to find out what pigments could be extracted from *Nereocystis*, (2) in thus doing to test Willstätter's and his co-worker's (1913, 1914) statement that the lower plants, such as algae, contain the four pigments found in higher plants, namely chlorophyll A and B, carotin and xanthophyll.

Most of the methods used in extraction, separation and identification were Willstätter's (1915). As one of the purposes of the work was to show the similarity between the pigments of the seed plants and the algae, the writer has applied the same tests to the kelp pigments as have been applied to the spermatophytes. Nettle (*Urtica*) was found very satisfactory by Willstätter (1915). It has been used as a comparison in this work.

The results were almost entirely qualitative. Very little attempt was made to make any quantitative determinations.

### **HISTORICAL**

The first work done on the extraction of pigments from green leaves was that of Grew (1862). He treated leaves with alcohol and got a green chlorophyll solution. Stokes (1864) did a great deal of work on pigment extractions. He found the coloring matter to consist of two green and two yellow pigments. All possessed highly distinctive optical properties. The work done from this date up to 1913 is reviewed by Czapek (1913). The work of Willstätter (1913, 1914, 1915) and his co-workers has placed the chemistry of pigments on a firm basis. He has established definite methods for extraction, and by means of chemical and spectrum analysis has determined the composition of these pigments. A very good summary of Willstätter's work is given by Jörgensen & Stiles (1915-1916) in *The New Phytologist*. This article takes up in great detail the methods of extraction used by Willstätter. Also other researches on the chemistry of chlorophyll are included in this review.

The essentials of recent work on pigments are that the leaf contains within the chloroplast four pigments, namely (1) chlorophyll A, (2) chlorophyll B, (3) carotin, (4) xanthophyll. The first two are

green, the last two yellow. Willstätter has made analyses of a great many different species at different hours of the day and at different seasons of the year. His work has been on algae, e. g. *Fucus*, *Laminaria* and *Ulva*, and on seed plants, e. g. nettle, grasses, etc. He has worked out formulae for certain derivatives of chlorophyll. He has established the fact that magnesium is the only metal found in chlorophyll ash. He believes chlorophyll to be in a colloidal state in the chloroplast. There has been a great deal of experimental evidence in support of this view.

Other workers since 1913 besides Willstätter are Marchlewski and Malarski (1914) who worked on chlorophyll derivatives, Iwanowski (1914) who discussed a physiological theory of chlorophyll. In 1915 there appeared a criticism by Pringsheim (1915). Stoklasa (1914) agrees with Willstätter except that in alcohol and acetone extracts of chlorophyll he found considerable amounts of potassium and phosphorous. Some work by Ewart (1915) shows the question of pigments is not an entirely settled one.

Much work has been done on pigment extraction in the marine algae. Much of this work has been an attempt to find out why the Rhodophyceae are red and the Phaeophyceae brown. To everyone familiar with brown seaweeds it is a well known fact that these plants, when exposed to the air, turn green very rapidly. This is perhaps most noticeable in the case of *Desmarestia*, which turns green almost immediately upon being taken out of the water. It also has the faculty of coloring all other seaweeds green with which it comes in contact. *Fucus*, *Nereocystis* and *Laminaria* also turn green, the thin portions, such as the fronds of the kelp, becoming green first. This change in color may also be brought about by treatment with boiling water, alcohol, etc.

A review of the history of the work done on the brown color of the Phaeophyceae may prove of value here. There has been argument about just what pigments are present and their nature; and question whether chlorophyll is present free in the chloroplast, or in chemical combination with some other pigments.

Cohn (1865) supposed the cells of the Phaeophyceae to contain a brown pigment called phaeophyll and closely related to chlorophyll. He believed it played the same role as chlorophyll does in higher plants. Rosenoff (1867) found chlorophyll in the Phaeophyceae but he thought it to be closely related to another pigment. Askenasy (1869) was able to separate green and yellow pigments. Sorby (1873) separated from 12 to 20 pigments all of which he claimed to be different substances. Among them was a blue chlorophyll, a yellow chlorophyll,

chlorofucine and fucoxanthin. He tested for them on the basis of difference in solubility and spectrum analysis. Reinke (1876) found phycoxanthin, which he says is not identical with xanthophyll of the higher plants. Engelmann (1882) presents two theories but gives no experimental evidence to prove either. Tschirch (1882) decided that all previously named substances are merely oxidation products of chlorophyll and are all contained in crude chlorophyll. Hansen (1885) separated a chlorophyll green and yellow which he called phykoxanthin; he also found a brown color, phycophäin. The green and yellow he found to be identical with those of the higher plants. Schült (1887) carried out a full treatment of the spectroscopic side. According to him the relation of the brown pigment to the chlorophyll has not been established. He regards phycophain as a special separate pigment without any relation to the chlorophyll series. Molisch (1894) showed that there is no such pigment as phycophain in the living cell. The change in color is due to a post-mortem product of the decomposition of a colorless chromogen.

Gaidukov (1903) worked on spectrum analysis. His analyses of *Fucus* and *Laminaria* agree with those of Hansen. He denied the existence of phycoxanthin, considering it a mixture of chlorophyll, carotin and phycophain, or of just carotin and phycophain. Molisch (1905) claims that it is an established fact that the brown algae owe their color to the presence of two pigments, a brown one called phaeophyll, and a green one called chlorophyll. The chlorophyll is masked by the brown, thus giving a yellow-brown or dark-brown color to the algae. By chemical change the phaeophyll is transformed into ordinary chlorophyll. He claims that this is what takes place when brown algae turn green in hot water. Phaeophyll has the same function in the seaweeds as chlorophyll has in the higher plants. He also reports the presence of a new substance called leucocyan, which, when treated with strong HCl, produces a blue-green pigment called phaeocyan. He reports carotin too. Tswett (1905) found that the natural color of brown algae is due to the presence of several pigments, among which is carotin. Tswett (1906) separated five pigments, two chlorophyllins (A and B), three yellows (carotin, fucoxanthin and fucoxanthophyll). Kylin (1912) extracted chlorophyll A and B from *Ascophyllum* and found it contained magnesium. He also found xanthophyll identical with that in the higher plants. He decided phycoxanthin to be a separate pigment because of differences in solubility between it and xanthophyll. Czapek (1912) found chlorophyll in amorphous form in the protoplasts of the brown seaweeds. He also found carotin, xanthophyll and fucoxanthin. Molisch (1913) again

claims that phycophäin is an after-death product. He believes that in the living chromophore, along with the chlorophyll, there is a brown chlorophyll which, through chemical change is converted into common chlorophyll. Tswett (1906) and Czapek (1911) maintained that chlorophyll is present in the protoplasts of the brown seaweeds, but masked by the yellows.

It remained for Willstätter and Page (1914) to complete the proof for this by spectroscopic analysis and the composition of the derivatives. The pigments of the Phaeophyceae were found to be identical with those of the higher plants with the exception of chlorophyll B, which is reduced in quantity. The yellow pigments are much more abundant than in higher plants. A third yellow pigment is found, which is probably the cause of the brown color called fucoxanthin by Willstätter. He has given it the formula  $C_{40} H_{56} O_6$ . It has been isolated from the mother liquid of the chlorophyll. Willstätter's formulae for the five pigments are:

Chlorophyll A— $C_{55} H_{72} O_5 N_4 Mg$ .

Chlorophyll B— $C_{55} H_{70} O_5 N_4 Mg$ .

Carotin— $C_{40} H_{56}$ .

Xanthophyll— $C_{40} H_{56} O_2$ .

Fucoxanthin— $C_{40} H_{56} O_6$ .

#### METHODS AND MATERIALS

The work was started at the Puget Sound Biological Station during the summer of 1919. Further work was done at the University of Washington during the following school year.

The material was all gathered from the water in front of the Biological Station. Only fronds were used, these being cut from the pneumatocysts while still in the water. This material was then hung on lines in the sun to dry. It dried very quickly and soon turned green. When thoroughly dry it was placed in a dark, dry box, ready for use.

It was first thought that the brown pigment in *Nereocystis* might cause trouble in the extraction of the other pigments. To avoid this, pieces of frond were cut up and placed in boiling water for 5 minutes. After this treatment the material was mixed with pure white sand and ground in a mortar. The gelatinous character of the mass, due to the presence of a large amount of colloidal material made grinding impossible; hence no good extractions could be obtained by this method and it had to be abandoned.

The idea was then conceived of allowing the material to dry after treatment with boiling water. The writer was then able to make successful extractions. Upon comparison these were found to be

identical with extractions made from fronds, taken from the water and immediately sun dried. Hence, to avoid the trouble of treatment with boiling water, material was directly dried upon being taken from the water.

An attempt was made to macerate the material with  $\text{Na}_2\text{CO}_3$ , but again difficulties were encountered with the colloids; that is, the whole mass became so thick and slimy that it was impossible to grind with sand and get any pigments.

#### EXPERIMENTAL WORK

A mortar was three-fourths filled with small pieces of dried frond, fine white sand was added and the contents ground to a powder with a pestle; then 85% acetone was added and more grinding done. The whole mass was then turned into a Büchner filter funnel previously fitted with a filter paper, the liquid being sucked through into a filter flask by means of an aspirator. A little more acetone was added to the mass to insure a large yield.

This acetone filtrate contained all the pigments (Jorgensen and Stiles 1916). These pigments were then transferred by a difference in solubility to petrol ether. This was done by placing the acetone extract and an equal amount of petrol ether in a separatory funnel. Distilled water was then added by pouring it gently down the sides, to prevent the formation of an emulsion. In a few minutes a separation took place; the upper ether layer contained the pigments. Traces of acetone were removed by repeated washings with distilled water. Each time the lower layer was removed. In a second separatory funnel some acetone extract was transferred to ether by the same process.

Next the two green pigments were separated. This was done by shaking 20 cc. of the petrol ether solution with 25 cc. methyl alcohol as nearly absolute as possible. Two layers then formed. The upper petrol ether layer now contained chlorophyll A. It was a pale blue-green. The lower layer, the methyl alcohol, now contained chlorophyll B. It was a pale yellowish-green. The methyl alcoholic phase was then transferred to ether in another separatory funnel. The difference in the shades of the two greens was due to carotin, an orange color, in the chlorophyll A; and xanthophyll, a yellow color, in chlorophyll B.

Now the yellow pigments were separated. This was done by saponification of the green pigments. This saponification was brought about by shaking an ether solution of all the pigments with methyl alcoholic KOH. Great care had to be taken to prepare this solution. As nearly absolute methyl alcohol as could be obtained and chemically pure KOH were used. A 20% solution was made (20 grams KOH

in 100 cc.  $\text{CH}_2\text{OH}$ ). This solution could only be used when fresh. Upon standing, resin aldehydes are formed. These caused the solution to become reddish brown. This was a weaker solution than that used by Willstätter but the writer used larger amounts to make sure of bringing down all the greens, that is, saponifying them.

Methyl alcoholic KOH and half as much ether solution were shaken together. The entire mass turned a yellowish brown. After a short time a green color reappeared. Then distilled water was slowly added and a little more ether. Upon shaking, two layers were produced; the heavy watery alkaline layer contained the greens and the upper ether one the yellows.

The remaining step now was to separate the two yellow pigments. 15 cc. of the ether solution just secured by the saponification with methyl alcoholic KOH were evaporated to 4 cc. This diluted with 40 cc. petrol ether, was mixed with 40 cc. methyl alcohol. Repeated washings were made with methyl alcohol until the alcohol came through clear. The petrol ether layer now contained the carotin, and the methyl alcohol the xanthophyll. The writer had succeeded in extracting and separating the four pigments, chlorophyll A and B, carotin and xanthophyll.

#### PURE SOLVENTS, FLUORESCENCE AND SAPONIFICATION

Tests were made to confirm Willstätter's (Jorgensen and Stiles, 1915) statement that pure solvents will not extract pigments. Benzine, acetone, ethyl alcohol and ether were used. Small pieces of dry frond were placed in test tubes containing 10 cc. of each solvent. These solvents were as nearly chemically pure as it was possible to get and keep them. At the end of two days these solvents were absolutely uncolored with the exception of the ethyl alcohol, which was a very pale green. This was explained by the fact that alcohol has a great affinity for water. These tubes were carefully watched for a period of two weeks but no change appeared.

Fluorescence was clearly seen in an acetone extraction of all pigments, also in an ether solution. It showed up plainly in the two greens, they appeared green by direct light, but red in reflected light. The same was true of the yellows. No fluorescence was seen in phaeophytin, the magnesium-free derivative. These findings are identical with extractions made from nettle leaves (Jorgensen and Stiles, 1916).

A brown ring was formed when a few drops of methyl alcoholic potash were introduced by means of a pipette, at the bottom of a test tube containing 10 cc. of an ether solution of all pigments. When this was done with great care the ring showed up plainly at the interface of the two liquids. Willstätter (Jorgensen and Stiles, 1916) says this

is due to the saponification of the chlorophyll to the potassium salt of the acid chlorophyllin. A very indistinct ring was secured when the saponification of chlorophyll A and B was tried.

The writer first tried Willstätter's (1915) method for the substitution of copper for magnesium but had little success. A second method suggested in Haas & Hill (1913) was tried with great success. Oxalic acid crystals were dissolved in 96% ethyl alcohol. This solution was then added to an alcoholic extract of kelp fronds. This extract was made by allowing cut pieces of fronds to stand in 95% ethyl alcohol for four days. The result was the formation of a considerable amount of white precipitate, which, when filtered and tested, was found to contain magnesium. The compound formed is called phytylphaeophorbide:  $C_{31} H_{51} N_4 (COOH) (COOCH_3) (COOC_{20} H_{39})$

The method used for determining the presence of magnesium was taken from Steiglitz (1911).

#### CRYSTALLIZATION

Small pieces of the frond were cut and allowed to stand for 12 hours in alcoholic KOH (20 gms. KOH and 80 cc. alcohol). These pieces were then washed in distilled water for 12 hours and cleared in glycerine for 2 days. Microscopic examinations were then made. Yellowish brown crystals were found varying in size from .016-.003 mm. (plate 5). These crystals compared almost exactly with the descriptions and plates of carotin and xanthophyll crystals in Molisch (1913). According to Molisch (1913) crystals of carotin and xanthophyll turn blue and dissolve in  $H_2 SO_4$ . The writer found this to be the case with these crystals in kelp. They were found only in the epidermis.

Strips of frond after they had been soaked in alcoholic KOH gave a decided blue color when treated with  $H_2 SO_4$ . Carotin and xanthophyll extractions of kelp when treated with  $H_2 SO_4$  gave a deep blue color almost instantly.

It was found unnecessary to cut sections for microscopic examination, as all coloring matter except carotin and xanthophyll had been extracted. The method followed was to strip off a piece of epidermis, mount in water and look directly through it.

An attempt was made to form ethyl chlorophyllide crystals in the following manner. Sections of fresh kelp were mounted in alcohol on slides and kept under a bell-jar in an atmosphere saturated with alcohol. These were allowed to stand for a day. When examined under the microscope green crystal-like bodies were found, somewhat three cornered in shape (plate 14). The writer does not feel at all sure that these were ethyl chlorophyllide crystals. Very little seems to be known about them (Palladin, 1918).





PLATE 14

Fig. 1. Carotin and xanthophyll crystals in isolated cells.  $\times 750$ .

Fig. 2. Probably ethyl chlorophyllide crystals.  $\times 700$ .

Fig. 3. Calcium sulphate crystals.  $\times 765$ .

Fig. 4. Calcium sulphate crystals in sieve tube.  $\times 850$ .

No good evidence of the presence of methyl chlorophyllide was secured. Strips of frond were allowed to stand in 75% methyl alcohol, 1 gm. of leaf and 4 cc. of alcohol. An abundance of calcium sulphate crystals was found (Karrer, 1916), some seeming to form in the sieve tubes (plate 14).

#### SPECTROSCOPIC ANALYSIS

These analyses were all made with a spectroscope in the physics department at the University of Washington. The best results were obtained by using two cells each 1 cm. thick. A comparison between kelp and nettle was made use of.

An acetone extract containing all the pigments gave the following absorption bands:

(1) All pigments together, in acetone.

#### Nettle

690.6—630.8

580.6—too faint to measure.

580.1—450.

#### Kelp

670.7—650.7

500. —too faint to measure.

496. —450.

- (2) Chlorophyll A, in petrol ether.

Kelp  
670.6—660.5  
467.0—450.0

- (3) Chlorophyll B, in methyl alcohol.

Kelp  
464. —450.

- (4) Carotin, in petrol ether.

Nettle	Kelp
475. —450.	476. —455.

- (5) Xanthophyll, in methyl alcohol.

Nettle	Kelp
465.5—450.	492.5—450.

#### CHLOROPHYLLASE AND CHLOROPHYLL

Chlorophyllase was demonstrated in the following manner. An acetone extract was made from dried fronds; this was diluted and then transferred to ether, 10 cc. was placed in a test tube and Na OH added. The contents were well shaken and the whole allowed to stand and carefully examined from time to time. After several hours the clear Na OH became slightly colored, more so after 24 hours. At the end of two days it was quite cloudy, brownish green in color. This is an indication of the presence of chlorophyllase (Jørgensen and Stiles, 1916) and its enzymic action. As this action proceeds more color is taken up by the Na OH. This reaction may be expressed chemically as follows:  $C_{32}H_{30}ON_4Mg(COOCH_3)(COOC_{20}H_{39}) + H_2O = C_{20}H_{39}OH + C_{32}H_{30}ON_4Mg(COOCH_3)(COOH)$ . Acid chlorophyllide is the name of the last compound given in the formula.

To demonstrate the destruction of chlorophyllase the same process was followed, except that the fronds were first treated with boiling water to destroy all chlorophyllase. With the kelp the writer was unable to demonstrate the complete destruction, there always appeared a slight discoloration of the Na OH layer, an indication of the presence of the enzyme.

Chlorophyll was secured in a colloidal state by evaporating 10 cc. of acetone extract to 2 cc., then stirring it into a large excess of distilled water, 50 cc. The evaporated chlorophyll was allowed to run down a pipette, which was used as a stirring rod in the meantime. The chlorophyll while in the acetone was a true solution. After it was evaporated and added to water, it was no longer a true solution but a colloidal solution of the suspensoid type. Chlorophyll is insoluble in water. Some tests were applied to show that this was a colloidal solution:

- (1) The solubility of this so called colloidal chlorophyll was

tested with ether, petrol ether and benzine. Two cc. of the colloidal chlorophyll was placed in each of three test tubes, respectively containing ether, petrol ether and benzine. The tube containing ether showed some slight indications of solubility, the others absolutely none.

(2) To each of these tubes was added 2 cc. of weak  $Mg\ SO_4$  solution. A few minutes after thoroughly mixing, the upper layers containing the solvents were colored green. The  $Mg\ SO_4$  precipitated the colloid, and the chlorophyll was enabled to go into true solution with the various solvents.

Some determinations of the nature of the electrical charge carried by colloidal chlorophyll were made. A colloidal solution of chlorophyll was prepared as before. It was placed in a U tube into the ends of which were introduced electrodes connected with a storage battery. A current at 10 volts was passed through. In six hours the liquid in the positive arm of the tube was more deeply colored than that in the negative, thus showing that kelp colloidal chlorophyll carried a negative charge. This checks with Willstätter's work (Jørgensen and Stiles, 1916).

#### QUANTITATIVE WORK AND STABILITY TESTS

Only a start was made on quantitative work and no definite data secured. All of this work was done at the University of Washington. The material was all gathered and dried at Friday Harbor and packed in boxes kept in a dry, dark place.

Colorimetric determinations were tried, but like all color tests, they were not entirely satisfactory. Willstätter (Jørgensen and Stiles, 1916) says in regard to quantitative determinations, that we cannot make them until all possible errors in the extraction and separation of pigments have been eliminated. He also suggests that quantitative spectroscopic determinations may prove useful as a further refinement in quantitative work. It is suggested by Jørgensen and Stiles (1916) that precipitation of chlorophyll by an electric current might offer a method for quantitative work of a high degree of accuracy.

In this quantitative work nettle pigments were again used as a comparison. All conditions affecting both extractions were kept as nearly identical as possible; 40 gm. of each were used. To insure more thorough drying both nettles and kelp were dried for two hours in an oven at 30°C. Two gms. of sand were used and 100 cc. of acetone; of the latter, 10 cc. were poured in while grinding the material in a mortar; the remaining 90 cc. were added in 10 cc. portions after the mixture had been put into the funnel and the connection made with the aspirator. The aspirator was kept running for 30 minutes for each kind of leaf.

These determinations were made in triplicate with practically the same results each time:

- (1) Yellows.  
From nettle, yellow.  
From kelp, browner than the yellow from nettle.
- (2) Greens.  
From nettle, deep green.  
From kelp, pale green.
- (3) Chlorophyll A.  
From nettle, blue green.  
From kelp, pale green.
- (4) Chlorophyll B.  
From nettle, yellow green.  
From kelp, more color than in kelp in (3).
- (5) Carotin  
From nettle, deep yellow or orange.  
From kelp, not so deep.
- (6) Xanthophyll.  
From nettle, pale yellow.  
From kelp, very pale yellow.

Tests showed the pigments to be more stable in nettle than in kelp. The greens held their color better than the yellows. In kelp acetone extraction of all pigments no color remained after 16 days. In nettle extraction some color still remained at the end of 3 weeks. In kelp chlorophyll B was found to be more stable than chlorophyll A.

#### PHAEOPHYLL OR PHYCOPHAEGIN

A little work was done on the brown pigment known as phaeophyll, phycophaein or fucoxanthin. Finely cut up pieces of kelp were allowed to stand in water for several days, then the whole was heated slightly. The water filtered from this appeared slightly brownish in color. A small portion of this water was treated with weak ammonium hydroxide ( $\text{NH}_4 \text{ OH}$ ); a yellowish precipitate was formed. Then sulphuric acid ( $\text{H}_2 \text{ SO}_4$ ) was added whereupon the precipitate disappeared. No such results were secured in control experiments. Pieces of fresh kelp placed in petrol ether or in glycerine and kept there for one week showed no change of color; but when placed in distilled water, hot water, alcohol, or exposed to warm air and sunshine, they turned a bright green.

#### SUMMARY

1. Pigments which can easily be extracted from kelp are. (1) Chlorophyll A, (2) Chlorophyll B, (3) Carotin, (4) Xanthophyll, (5) Fucoxanthin.

2. Magnesium is present in chlorophyll.
3. There is good evidence that chlorophyllase is present.
4. Kelp chlorophyll can be put into a colloidal state.
5. This colloidal chlorophyll carries a negative charge.
6. These pigments cannot be extracted by pure solvents.

The writer is indebted to Dr. G. B. Rigg, of the University of Washington, at whose suggestion the work was started, for assistance and criticisms.

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# Effects of Thyroid and Iodine Feeding upon the Metamorphosis of two Species of Crab

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This work, undertaken at the suggestion of Dr. Bennett M. Allen, of the University of Kansas, purposed to ascertain the effects of thyroid and iodine feeding upon the metamorphosis of megalops to crab. It had previously been shown that in amphibians such feeding markedly accelerated metamorphosis.\* Its effects upon mammalia, notably cretins, are well known, and equally marked. Whether such feeding would, however, produce and maintain an acceleration in metamorphosis in an animal possessing no thyroid tissue a search of the literature showed was yet unascertained. These experiments, carried out during July and August 1920 at the Puget Sound Biological Station at Friday Harbor, Washington, cover 2085 megalops.

## MATERIAL

Megalops are positively phototropic. After unsuccessfully trying various daylight plankton tows, megalops for this experiment were collected at night by suspending a shaded brilliant electric light close over the surface of the water. The animals were dipped up with a large coffee strainer as they rose to the light. Largest catches were obtained during the turn of extreme high tide; at other tides the current carried megalops into and beyond the cone of light before there was opportunity for response. Several runs of fish into the harbor depleted for a considerable time the supply of all larval crustacea. The temperature of the water was constant within a few degrees of 10° C.

Two species of megalops were chosen. The larger, of which some 600 were used, was 3.5-4.0 mm in length, and metamorphosed into a crab, *Cancer magister*, about 6 mm each way. The smaller and more abundant, of which 1485 were used, was 2.5-3.0 mm in length, and metamorphosed into a crab, *Cancer gracilis*, about 4 mm each way. The species were determined by Professor Trevor Kincaid of the University of Washington.

## HISTOLOGY

Examination of serial sections of both species of megalops fails to

\*For bibliography, see W. W. Swingle; Studies on Relation of Iodine to Thyroid, Jour. Exp. Zool. 27: 415 and 425. 1918.



reveal any trace of thyroid tissue. The liver is abundant and easily recognizable as such; it is coloration in this tissue which, more than any other factor, allows detection of dyed food. No trace of the gonads, and only uncertain evidences of the green antennal glands, were found. There is no evidence in any glandular structure of megalops either of the colloid peculiar to thyroid tissue, or of the characteristic vesicles lined with cuboid epithelium.

#### PLAN OF EXPERIMENTS

Megalops were fed compounds of thyroid tissue, or of iodine, and various controls kept under as nearly similar conditions as possible, the only variation being in the material upon which the animals were fed. Daily account was kept of the number of metamorphoses in each dish; those animals which died while in process of shedding their shell were counted as metamorphosed.

Since liver was used throughout the experiment as the normal basis of food, a compound of liver and thyroid (or iodine) could have been employed for the detection of specific effect of the active agent, if it had not been that such mixtures of liver and thyroid (or iodine) resolve in the water into cloudy masses so lacking in solidity that megalops, which feed by holding a solid particle of food in contact with their mandibles, will not ingest food in such form. Flour, however, is a satisfactory agent for binding a matrix; on account of its light color, though, a dye must be used to enable detection when ingested.

A moistened mixture of thyroid powder is also comparatively light in color; hence, in order to be sure the thyroid was actually eaten, dyes were introduced which made the food visible through the thin chitinous shell of the animal. The iodine mixture, however, was dark enough when ingested to be visible without the aid of dyes.

In order to narrow as definitely as possible detection of specific effects, the following system of feeding was developed:

1. Animals were starved: to ascertain the normal death rate when they fed upon themselves.
2. Liver alone was fed: to eliminate cannibalism as far as possible, and to establish the experimental normal rate of metamorphosis.
3. Both liver and flour were fed: any considerable deviation in rate of metamorphosis from that shown by (2) would indicate an effect produced by flour alone.
4. Both dye and flour were fed: any considerable deviation in rate of metamorphosis from that shown by (3), if (2) and (3) were in substantial agreement, would indicate an effect due to dye alone.
5. Both flour and thyroid were fed: any considerable deviation

from that shown by (3), if (2) and (3) were in substantial agreement, would indicate an effect produced by thyroid alone.

6. Dye, thyroid and flour mixture was fed: any considerable deviation in rate of metamorphosis from that shown by (4) would indicate an effect due solely to the thyroid. This should check substantially with results in (5).

#### PRELIMINARY WORK

*Liver.* Megalops are cannibals and have voracious appetites. Fine particles of desiccated liver were, however, acceptable food, and apparently produced no marked effect either in advancing or retarding the rate of metamorphosis.

*Iodine.* One part of iodine was thoroughly ground with one hundred parts of flour. The mixture was made into a smooth paste and dried in a thin layer upon glass. The resultant scale was broken into fine flakes and kept dry in corked bottles. This compound was ten times as strong in iodine content as the thyroid mixture used in this experiment, but other experimental work has shown that elementary

TABLE 1. Showing data which led to the selection of dyes used.

	Fed dyed food 11:30 p. m. July 26; water changed and liver fed 10:00 a. m. July 27.			Fed dyed food 10:30 a. m. July 27; water changed and liver fed 6:00 p. m. July 27.		
	Dye taken by animal	Dye taken by water	Animals alive after 2 days	Dye taken by animal	Dye taken by water	Animals alive after 2 days
Carmine rubr. opt.	—	—	—	—	—	—
Congo red	—	—	—	—	—	—
Eosin	±	+	—	—	+	—
Ethylrosin pur.	—	±	—	—	±	—
Fuchsin	±	+	—	—	+	—
Gentian violet	—	—	—			
Lichtgrün	+	±	+			
Magdala red	—	—	—	—	±	—
Malachite green	—	—	—			
Methylene blue	±	+	—	—	+	—
Methyl orange	±	+	—	±	+	—
Orange G	+	±	+			
Toluidene blue	±	+	—	—	+	—
Victoria blue	+	—	—			

iodine is less readily absorbed than that organic form present in the thyroid gland itself.

*Thyroid.* Equal parts of thyroid extract (Lilly's 0.2% active  $I_2$ ) and white milled flour were mixed in a paste and dried in a thin layer on glass. When dye was used (see below), it was dissolved in the water with which the paste was made. The scale was broken into fine flakes and kept dry in corked bottles.

*Dyes.* A number of dyes were experimented with, resulting in the selection of (Grubler's) Lichtgrün and Orange G, and Victoria Blue (alcoholic solution). A thyroid flour mixture containing lampblack was also made up.

*Dishes.* Megalops were to be placed, 25 to a group, in glass bowls 15 cm in diameter and 6-8 cm deep. With sufficient added food, cannibalism is not marked in dishes of such size.

*Logs.* Each dish contained a small block of wood upon which the megalops occasionally crawled; the block was not allowed to become water-soaked nor sour.

#### PROCEDURE

Megalops were caught at about 11 in the evening, kept in large dishes, and given a feeding of the material desired. The following morning those individuals showing evidences of having eaten the material were transferred to the smaller dishes in lots of 25.

The dishes were washed, the water changed, and a small amount of fresh food added daily. Old food and dead or metamorphosed megalops were removed at the same time. The amount of fresh food added was always more than the animals could eat, and never enough to foul the water. That the food was eaten was evidenced by the appearance of feces throughout the experiment.

#### DISCUSSION OF GRAPHS

The following graphs summarize the work. For purposes of direct comparison all graphs have been reduced proportionally to a basis of 100 animals. They show cumulative figures, since this form furnishes not only the rate of change (shown by the slant of the curve), but also gives at a glance the absolute number of animals involved in any change. In all graphs each abscissal division represents one day, and each ordinal division represents five animals.

In an experiment of this type, where animals are observed statistically in relatively small numbers, any result obtained should be of comparatively large magnitude before it is accepted as being an induced deviation from normal variation. Variations shown by the graphs have been, accordingly, scanned not only with regard to divergence shown but also with regard to the number of animals involved. Graphs

1-9 show substantial agreement in all types of feeding. Graph 10 is a polygon showing the agreement in acceleration of metamorphosis.

GRAPH 1. Starvation curves, 150 animals (50 3.5-4.0; 50 2.5-3.0); Aug. 8th-20th.

This graph summarizes the result of feeding proposed by (1) under "Plan of Experiment." Metamorphosis 27; death 73.

GRAPH 2. Liver-flour, 200 animals (25 3.5-4.0; 175 2.5-3.0); Aug. 4th-14th. Liver: 175 animals (75 3.5-4.0; 100 2.5-3.0); different periods from July 30th to Aug. 20th.

This graph summarizes the results of feeding proposed by (2) and (3), "Plan of Experiment." The lower number of metamorphoses in the liver-flour is compensated by the higher death rate. The rates of metamorphosis, as shown by the slants of the solid curves, are substantially coincident.

GRAPH 3. Dye-flour, 300 animals (75 3.5-4.0; 125 2.5-3.0; 100 mixed 2.5-3.0 and 3.5-4.0); different periods from July 30th to Aug. 13th. Liver: 175 animals (75 3.5-4.0; 100 2.5-3.0); different periods from July 30th to Aug. 20th.

This graph summarizes the results of feeding proposed by (4), "Plan of Experiment." Although the solid lines show separation, nevertheless the rates are substantially parallel after the first day. Note that the rate of dye-flour metamorphosis agrees closely with that shown in graph 1, still further indicating no specific effect due to the dyes used. The heavy lines of this graph are composites of the dye-flour lines shown in graphs 6, 7, and 8.

GRAPH 4. Thyroid-flour, 200 animals (75 3.5-4.0; 125 2.5-3.0); different periods from July 30th to Aug. 20th. Liver, 175 animals (75 3.5-4.0; 100 2.5-3.0); different periods from July 30th to Aug. 20th.

This graph summarizes the results of feeding proposed by (5), "Plan of Experiment". Graph 2 indicates the equivalence of liver and liver-flour curves. This present graph therefore shows the nullity of any specific action of thyroid upon either the rate of metamorphosis or the absolute numbers affected.

GRAPH 5. Thyroid-flour, 200 animals (75 3.5-4.0; 125 2.5-3.0); different periods from July 30th to Aug. 20th. Dye-thyroid-flour, 300 animals (150 3.5-4.0; 100 2.5-3.0; 50 mixed 2.5-3.0 and 3.5-4.0); different periods from July 30th to Aug. 13th.

The light lines of this graph are the composite results of the dye-thyroid-flour lines shown in graphs 6, 7, and 8. It therefore summarizes the results of feeding under (6) under "Plan of Experiment", by showing the agreement between the two types of thyroid feeding; and further (through graph 4), by showing agreement with the effect produced by ordinary food, again demonstrates the nullity of any specific action of the thyroid.

GRAPH 6. Lichtgrün-flour-thyroid, 100 animals (75 3.5-4.0; 25 2.5-3.0); different periods from July 30th to Aug. 14th. Lichtgrün-flour, 100 animals (50 3.5-4.0; 50 2.5-3.0); different periods from July 30th to Aug. 20th.

GRAPH 7. Orange G-flour-thyroid, 100 animals (50 2.5-3.0; 50 mixed 2.5-3.0 and 3.5-4.0); different periods from Aug. 4th-13th. Orange G-flour, 100 animals (25 3.5-4.0; 75 2.5-3.0); Aug. 4th-12th.

GRAPH 8. Victoria Blue-flour-thyroid, 100 animals (25 3.5-4.0; 75 2.5-3.0); different periods from Aug. 3d-12th. Victoria Blue-flour, 100 animals (mixed 2.5-3.0 and 3.5-4.0); Aug. 3d-10th.

These graphs, from which data for graphs 3 and 5 were drawn, indirectly confirm the results of feeding proposed under 4 and 6 under "Plan of Experiment." Note that while graph 7 shows a higher metamorphosis due to thyroid, as compared with the flour curve for that graph, yet graphs 6 and 8 show a lower rate for thyroid, as compared with their flour curves. The substantial agreement in the solid lines of each graph indicates that the dyes themselves have no effect upon metamorphosis, and, since graph 2 indicates the nullity of any specific action of the flour, the present graphs, experimentally precedent to graphs 3 and 5 forecast the negative result of the experiment through the coincidence of the thyroid and the flour curves.

GRAPH 9. Thyroid-flour, 80 animals (40 3.5-4.0; 40 2.5-3.0); July 26th-Aug. 10th. Liver, 80 animals (40 3.5-4.0; 40 2.5-3.0); July 26th-Aug. 10th.

This graph represents a simpler preliminary experiment carried out under more ideal weather conditions. Eliminating the uncertainty as to the consumption of the thyroid-flour mixture (beyond the continued appearance of feces), and the uncertainty as to any effect the flour or the liver might have, this graph again indicates, through the coincidence of the slant and the height of solid lines, the nullity of any specific effect produced by the thyroid.

GRAPH 10. Iodine-flour, 250 animals (100 3.5-4.0; 150 2.5-3.0); different periods from Aug. 5th to Aug. 14th. Liver, 175 animals (75 3.5-4.0; 100 2.5-3.0); different periods from July 30th to Aug. 20th.

The nullity of the action of the flour having been indicated in graph 2, this present graph demonstrates the lack of any specific effect of iodine upon either the rate or the absolute number of metamorphoses.

GRAPH 11. Iodine-flour, 75 animals (75 2.5-3.0); July 26th-Aug. 10th. Liver, 75 animals (75 2.5-3.0); July 26th-Aug. 10th.

This graph represents a simpler preliminary experiment carried out under better weather conditions. Its seeming positive specific action of iodine is belied by graph 10, and vitiated by its extremely high death rate.

GRAPH 12. Polygon showing the number of megalops metamorphosing each day.

This graph still further shows absence of any specific effect due either to thyroid or iodine. Note also that the composite curve approximates a normal probability curve drawn without skew.

#### GENERAL CONSIDERATIONS

August 6, 7 and 8 were very warm days, and although the laboratory is located only a few feet above water, the temperature of the laboratory and of the water in the bowls containing the megalops rose markedly; the death rate was disproportionately high on these days. The two preliminary experiments (graphs 9 and 11), however, carried out, at least in the earlier stages, under more ideal weather conditions, confirm the results obtained in the later experiments.

The smaller species of megalops has a death rate much higher than the larger; however, the segregation of the two species, and the separate plotting of results for each, does not alter the conclusion reached in this paper. Hence, only combined figures are given here. With but two exceptions (of one each) no megalops were on hand at the time an experiment was discontinued.

The high death rate evidenced in these experiments would not seem to vitiate the results beyond an effect due to the depletion of numbers worked with, and the consequent magnification of individual variation which might be untrue for the mass.

Commercial lampblack, instead of cuttlefish India ink, was used as a dye in one experiment with unfortunate results (1% metamorphosis; over 150 died in two days; 200 died in seven days). Hence, the curves for the use of lampblack as a dye, especially desirable because this inert substance could not possibly produce any effect of its own, are omitted because the extremely high death rate obliterates completely their value.

#### CONCLUSION

These experiments indicate that neither thyroid tissue nor iodine produce any demonstrable effect upon the rate of metamorphosis of megalops to crab.

## PLATE 15

Graph 1. Heavy solid, metamorphosis; heavy dash, unmolested death; light solid, missing; light dash, eaten; dot dash, total mortality.

Graph 2. Heavy solid, liver-flour metamorphosis; heavy dash, liver-flour death; light solid, liver metamorphosis; light dash, liver death.

Graph 3. Heavy solid, dye-flour metamorphosis; heavy dash, dye-flour death; light solid, liver metamorphosis; light dash, liver death.

Graph 4. Heavy solid, thyroid-flour metamorphosis; heavy dash, thyroid-flour death; light solid, liver metamorphosis; light dash, liver death.

Graph 5. Heavy solid, thyroid-flour metamorphosis; heavy dash, thyroid-flour death; light solid, dye-thyroid-flour metamorphosis; light dash, dye-thyroid-flour death.

Graph 6. Heavy solid, Lichtgrün-flour-thyroid metamorphosis; heavy dash, Lichtgrün-flour-thyroid death; light solid, Lichtgrün-flour metamorphosis; light dash Lichtgrün-flour death.

Graph 7. Heavy solid, Orange G-flour-thyroid metamorphosis; heavy dash, Orange G-flour-thyroid death; light solid, Orange G-flour metamorphosis; light dash, Orange G-flour death.

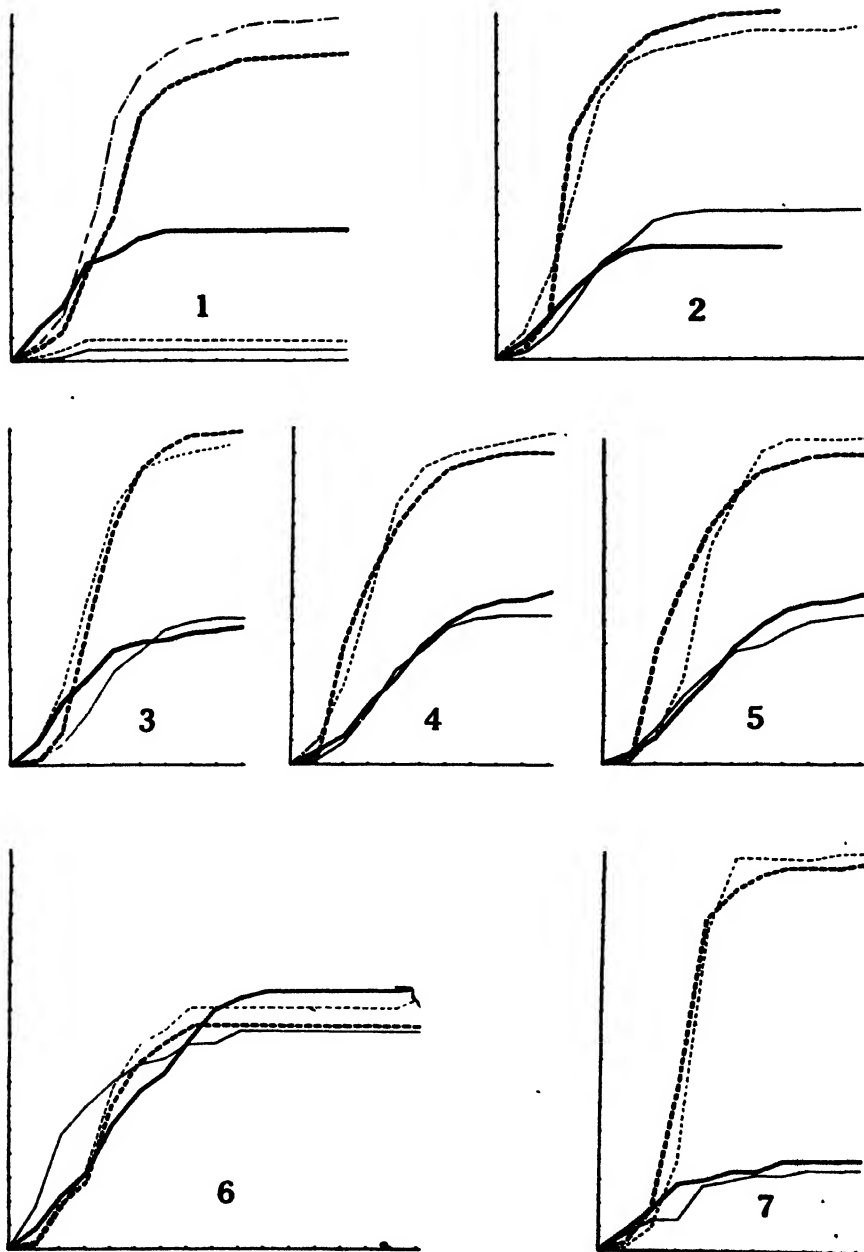


PLATE 15



## PLATE 16

Graph 8. Heavy solid, Victoria Blue-flour-thyroid metamorphosis; heavy dash, Victoria Blue-flour-thyroid death; light solid, Victoria Blue-flour metamorphosis; light dash, Victoria Blue-flour death.

Graph 9. Heavy solid, thyroid-flour metamorphosis; heavy dash, thyroid-flour death; light solid, liver metamorphosis; light dash, liver death.

Graph 10. Heavy solid, iodine-flour metamorphosis; heavy dash, iodine-flour death; light solid, liver metamorphosis; light dash, liver death.

Graph 11. Heavy solid, iodine-flour metamorphosis; heavy dash, iodine-flour death; light solid, liver metamorphosis; light dash, liver death.

Graph 12. Polygon showing the number of megalops metamorphosing each day. Heavy solid, dye-thyroid-flour; light solid, liver; light dash, thyroid-flour; light dot-dash, iodine-flour.

Fig. 13. Sketch of the 3.5-4.0 mm. megalops.

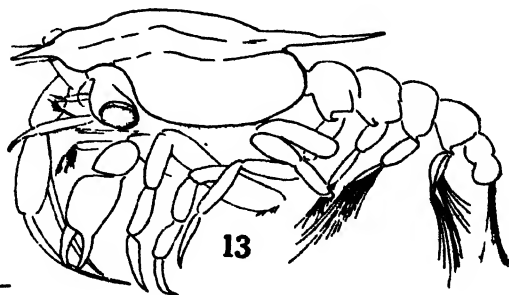
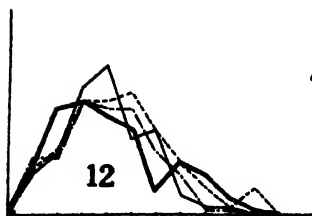
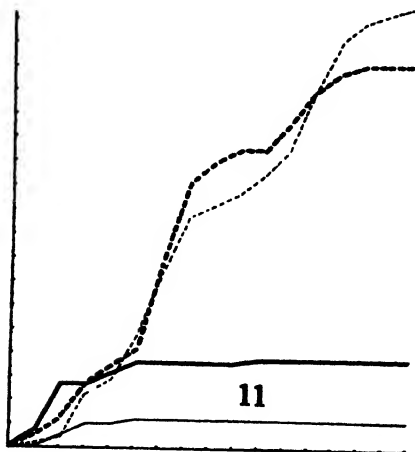
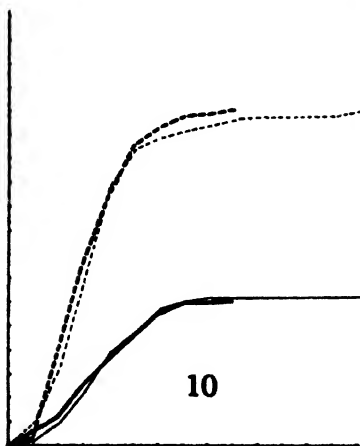
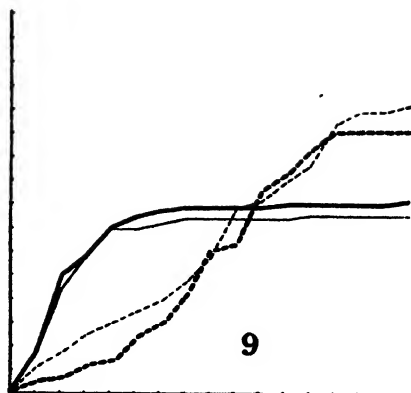
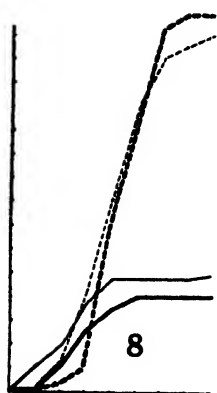


PLATE 16



# **Axial Metabolic Gradients in the Early Development of the Sand Dollar, *Dendraster excentricus***

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The existence of axial gradients in susceptibility to lethal concentrations of various toxic substances has been demonstrated in both embryonic and adult stages of many animals and of several plants by Child, Hyman and Bellamy. The results of investigations including studies of susceptibility to and inhibition by a large number of agents such as cyanides, acids, alkalies, salts of the heavy metals, lack of oxygen, alcohols, anaesthetics and vital dyes (for full references see Child, 1920); of differences in electrical potential (Hyman, 1918 and unpublished data); and of the rate of oxygen consumption (Hyman and Galigher, 1921) and carbon dioxide production (Robbins and Child, 1920) of different regions along the physiological axes all indicate that the underlying causative factors of the susceptibility gradients are, primarily at least, graded differences in rate of metabolic activity. On this basis Child has drawn certain conclusions concerning the significance of such gradients in organic individuation and development (Child, 1915a, 1920, 1920a).

The developmental stages in which these gradients have been studied include coelenterates (Child, 1919), flatworms (Child, 1915a), annelids (Child, 1917), echinoderms (Child, 1915, 1916, 1916a) and chordates (Bellamy, 1919 and unpublished evidence). Hyman (1916) has studied the gradients in relation to regeneration and development in several species of microdrilous oligochaetes and, more recently, in the embryos of *Fundulus* and *Tautoglabrus* (Hyman, 1920) and of the chick (unpublished). Bellamy (1919) has studied the gradients and their role in the development of the frog.

The present investigation was undertaken with the object of studying the susceptibility gradients both in early development and metamorphosis, but due to the difficulty of rearing the larvae through metamorphosis, I have so far been unable to obtain, except in one case, stages more advanced than the fully developed pluteus. However it is hoped at a later date to study the physiological changes involved in metamorphosis.

### MATERIAL AND METHODS

Abundant material of the sand dollar was obtained at low tide in False Bay, San Juan island, Washington.

It was found that material kept in a deep (4-5 feet), covered live car usually would not extrude reproductive products; but that when specimens were removed to a shallow car (about 8 inches deep) on a warm, sunny day, sperm or eggs would usually be discharged by a good many. By this method, for which I am indebted to Professor D. M. Allen of the University of Kansas, I was able to obtain material almost at will. However, as eggs so obtained were very apt to be fertilized before removal to the laboratory, the unfertilized eggs used in these experiments were obtained by opening specimens which had been washed in fresh water, removing the gonads and agitating them in a finger bowl of sea water.

When necessary the eggs were fertilized by adding a few drops of dilute sperm suspension to a fingerbowl of sea water, the bottom of which was covered by a single layer of eggs. As soon as fertilization membranes had been formed by a large percent of the eggs the water in the dish was poured out and the eggs were washed with sea water several times in order to remove any remaining sperm. Eggs which were already fertilized when collected were distributed in fingerbowls so that the bottom of each receptacle was covered by not more than a single layer of eggs. When the majority had formed swimming blastulae these were transferred to larger receptacles in which the water was changed frequently. Material treated in this manner yielded normal larvae in large numbers.

The methods used to demonstrate the gradients are as follows:

1. The direct susceptibility method described by Child (1913 and later papers). The reagents used are KCN M/100-300 and rather weak solutions of  $\text{NH}_4\text{OH}$  (filtered solution made by adding about 15 drops of commercial ammonia water to 100 cc. of sea water). When the earlier stages are placed in such solutions movement ceases in from one half minute to half an hour or longer, the exact time depending upon the concentration of the solution and upon the physiological condition of the material. Soon after cessation of movement death and disintegration begins, first in the apical regions of blastulae and gastrulae or at the tips of the arms of plutei, and then spread backward over the body. The progress of the death gradient is marked by a swelling and splitting off of the cells, and finally by the loss of all definite structure in the parts concerned.

In the later stages it is very difficult to demonstrate the gradients

by this method, especially by the use of potassium cyanide, as when differentiated connective tissue is present the larvae do not disintegrate readily, but merely become opaque.

2. The gradients in stages later than the gastrula are much more readily demonstrated by intra-vitam staining with neutral red followed by removal to cyanide or ammonia solutions. In material treated in this manner the death gradient may be followed by observing the gradual change in color from red to yellow and finally in the loss of color, due to the alkaline reaction of such solutions.

3. Although the gradients may be quite satisfactorily demonstrated by the above methods, they are even more clearly shown by the use of dilute solutions of potassium permanganate, as described by Child (1919). When specimens are placed in such a solution, a very marked staining gradient may be observed, the apical regions being the first to show a distinct brown color due to reduction of the permanganate by oxidative processes going on within the cells, and at the end of the reaction (i.e. death), these are the most deeply stained parts.

#### GRADIENTS IN THE UNFERTILIZED EGG

The polarity of the matured egg is marked by the excentric position of the nucleus. By any of the methods just described a cytoplasmic gradient may be observed. The most susceptible or most deeply stained region of the egg lies at the surface in the region where it is most closely approached by the nucleus (Fig. 1) and the gradient runs back over the egg along what appears, according to the position of the nucleus, to represent the major axis (Figs. 1-3).

Child (1916) suggests that the gradient in the egg of the sea urchin arises as the result of a differential in oxygen supply from the surface of the ovary inward. This interpretation is confirmed by observations and experiments made upon the sand dollar and upon the starfish, *Pisaster ochraceus*. In the microscopic examination of parts of ovaries of these forms it was found that the nuclei of the ovocytes lay in that part of the cytoplasm which had the greatest external exposure, and on teasing parts of ovaries into cyanide and permanganate solutions it was found that the susceptibility and staining gradients in the ovocytes had their highest points in the regions of the cells in which the nuclei most nearly approximated the cell surfaces, and therefore in the parts of ovocytes which in the ovary had the greatest external exposure. Thus in the sand dollar and the starfish, the graded differences in rate of activity in the egg and consequently, perhaps, of the later stages probably arise under the influence of a graded differential in the environment. That

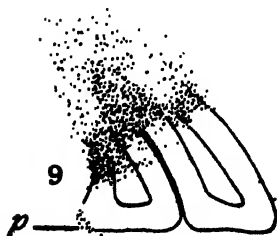
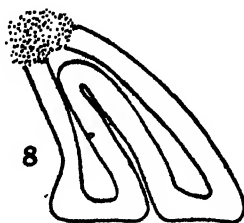
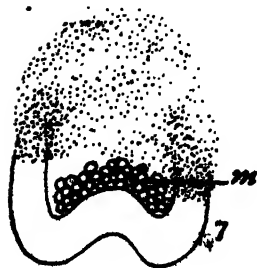
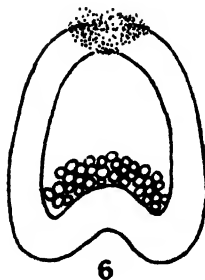
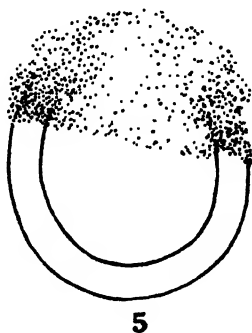
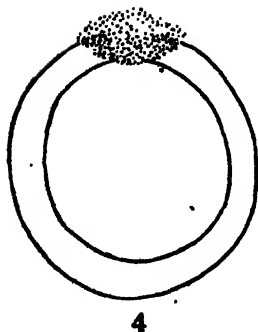
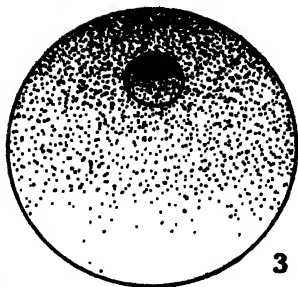
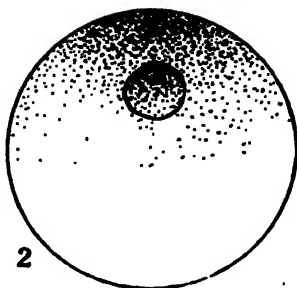
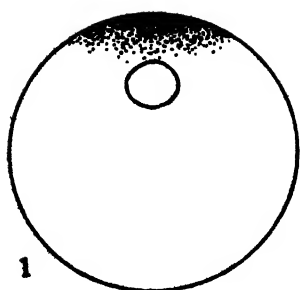


PLATE 17

the polarity of the frog's egg arises through the influence of a similar differential, that of blood supply, is held by Bellamy (1919).

#### CLEAVAGE STAGES AND BLASTULA

In the two cell stage each of the blastomers exhibits a polar susceptibility gradient, the gradients in the two blastometers being parallel, although almost invariably one of the two blastomeres is distinctly more susceptible than the other.

In the four cell stage the susceptibility relations are essentially the same as those just described for the two cell stage, there being a polar gradient in each of the blastomeres and one or two of the blastomeres usually being more susceptible than the others.

In the eight cell stage the polar gradients in the blastomeres are not well marked, but the circlet of four cells at one end is, in the few cases observed, of higher susceptibility to potassium cyanide than is the adjacent group of four cells. In this stage it was also observed that one or two cells of each group of four are more highly susceptible than the others of the same circlet.

Very few observations were made on later cleavage stages. The only fact shown was that secondary regions of high susceptibility may appear in almost any part in these stages and that in general the polar gradient, though undoubtedly present, is more or less masked by these. These secondary regions of great susceptibility probably indicate cells or groups of cells in the process of division.

In the early, almost spherical blastula, before movement has commenced, the gradient in susceptibility to cyanides and ammonia and in ability to reduce potassium permanganate is readily observed. Disintegration or staining begins at one region of the surface and gradually spreads over the surface along an axis which probably represents the

#### PLATE 17

Figs. 1-3. Three successive stages in the staining of the matured egg in a weak solution of potassium permanagnate, showing nuclear and cytoplasmic gradients and their coincidence.

Figs. 4-5. Two stages in the disintegration of an early blastula in KCN M/150, showing the polar gradient and the greater susceptibility of one side of the blastula.

Figs. 6-7. Two stages in the disintegration of an early gastrula in  $\text{NH}_4\text{OH}$ , showing the polar gradient, the greater susceptibility of one side and the relatively low susceptibility of the mesenchyme (m).

Figs. 8-9. Two stages in the disintegration of a very late gastrula in  $\text{NH}_4\text{OH}$ , showing the greater susceptibility of the oral side, the polar gradient and the secondary gradient in the archenteron, also the regions of high susceptibility preceding the appearance of the postoral arms (p).



major axis which is not morphologically defined until a later stage (Figs. 4 and 5).

In the later, somewhat elongated blastula (Figs. 6-7) the apico-basal susceptibility and staining gradient is coincident with the major axis, the region of highest susceptibility and greatest ability to reduce potassium permanganate being the smaller anterior end, that of least, the broader posterior end.

In the later blastula, and to some extent in the earlier blastula it is apparent that the disintegration or staining wave progresses with greater rapidity down one side than down the other.

In the foregoing paragraphs it has been shown that in the undivided egg there exists a gradient in susceptibility and in ability to reduce potassium permanganate which is undoubtedly the manifestation of a gradation in rate of metabolic activity which has arisen through the influence of a graded differential in the environment; that in the two and four cell stages each blastomere exhibits a similar gradient; that in the eight cell stage one group of four blastomeres is more highly susceptible than the other; that during later cleavage a polar susceptibility and staining gradient is usually apparent though it may be masked by secondary regions of high susceptibility which may be indicative of blastomeres or groups of blastomeres in the process of division; that in the early blastula there is a polar susceptibility gradient; and that in the later, elongated blastula, the polar susceptibility gradient is coincident with the major axis. However, in the total absence of landmarks in these stages, it can not be concluded with absolute certainty that the gradient in the egg persists through cleavage and that that of the blastula does not arise *de novo*. But it is known that in many cases, at least, the morphological polarity of the egg does persist, and if it is true, as all the evidence indicates, that visible polarity is the expression of the metabolic gradient, we must suppose that the gradient itself is persistent and that upon its persistence depends the persistence of morphological polarity.

#### GASTRULA

In the early gastrula the susceptibility and staining relations are essentially the same as those described for the later blastula. In the later gastrula in which the archenteron has begun to grow forward there is a secondary gradient in this structure from the growing tip backward.

In the later gastrula the greater susceptibility of one side which has already been described for the earlier stages becomes much more marked, and in the very advanced gastrula (Figs. 8-9) in which the future oral side has become flattened. disintegration or staining pro-

gresses with much greater rapidity down this side than over the rest of the surface.

Here again, as in the case of the polar gradient, there arises in consequence of the absence of landmarks the difficulty of proof that a region of high susceptibility in an early stage is continuous with one which in a later stage is associated with the formation of a definite morphological region of the organism. In this case also the evidence is supplemented by the knowledge that in some forms, at least, definite blastomeres or groups of blastomeres may persist to give rise to definite structures; and, although the type of structure to arise is undoubtedly determined by the specific constitution of the protoplasm, the position in which the structure arises has, I believe, been shown to be dependent upon the position of the formative region in relation to the gradients. Therefore if a formative region for the highly susceptible oral side of the larva is present in the blastula of the sand dollar, as it is in many other forms, and as is indicated by the presence of a lateral region of high susceptibility, its function as such must depend upon its relative rate of activity and its persistence to so function may be sustained only by maintenance of this relative rate. And if the sand dollar is not radically different in this respect from many other animal forms it must be concluded that the more highly susceptible side of the blastula represents the oral side of the very late gastrula and of later stages, and that its function as such is dependant upon its maintenance of the high rate of metabolic activity indicated by its great susceptibility.

#### GRADIENTS IN THE FORMATION OF THE PLUTEUS LARVA

The susceptibility and staining relations of the prepluteus are essentially identical with those just described for the very late gastrula, there being a general body gradient and the oral side being of relatively high susceptibility.

However with the development of the triradiate skeletal spicule two secondary regions of high susceptibility appear, one on each side of the oral surface where it is approached by the skeletal rods destined to form the skeleton of the postoral arms. These regions of high susceptibility seem to appear before the skeletal rods come into contact with the ectoderm, and certainly before any traces of outgrowths are present (Fig. 9).

The appearance of the antero-lateral (Fig. 9), postero-dorsal (Fig. 12) and preoral arms (Fig. 13) is also preceded by the establishment of regions of high susceptibility and ability to reduce potassium permanganate.

However at all times the preoral lobe as a whole, and particularly its anterior region, remains the major region of high susceptibility and there is a well marked gradient down the body surface.

In each of the arms of the pluteus there is an apico-basal gradient in susceptibility, and in ability to reduce potassium permanganate although these gradients are masked somewhat by the high susceptibility of the ciliated bands at all points. It is worthy of note that before the outgrowth of any pair of arms begins, the regions which will give rise to them have attained a degree of susceptibility at least equal or usually greater than that of the preoral lobe itself. It may be suggested therefore that the growth of each arm may be looked upon as depending upon the isolation of a particular region from the physiological control of the preoral lobe region. This isolation is most probably accomplished by the stimulation of the "formative regions" by skeletal growth. This view is supported by the experiments of Herbst, who observed that in the larva of the sea urchin no arms were formed when the skeleton was lacking and vice versa.

With the formation of the massive skeletal aggregation at the posterior end of the body this region also becomes one of high susceptibility (Figs. 13 and 14).

In observing the reduction of potassium permanganate by the later larvae I was struck by the fact that at the end of the reaction (i.e. death) the enteron appeared to have taken on a deeper brown color than the greater part of the ectoderm, although in the earlier stages the ectoderm was clearly capable of reducing more of this substance than the entoderm. This seeming discrepancy led me to suspect that this appearance was due to the thickness of tissue through which the enteron was viewed in the later stages. This hypothesis was confirmed by the study of paraffin sections of larvae stained in this manner. These sections also revealed that the coelomic mesoderm was, as would be expected from the fact that in these stages it is a very active tissue, more deeply stained than either ectoderm or entoderm. Very satisfactory sections of such material were obtained when the processes of dehydration, clearing and infiltration were greatly abbreviated, but such preparations are not permanent, becoming entirely bleached in the course of a few weeks.

In the older plutei (Fig. 14) the gradients are much less marked than in the earlier stages, the gradients in the arms of stages later than that shown in Fig. 14 becoming nearly if not quite obliterated and the differences in susceptibility, and consequently in metabolic rate and

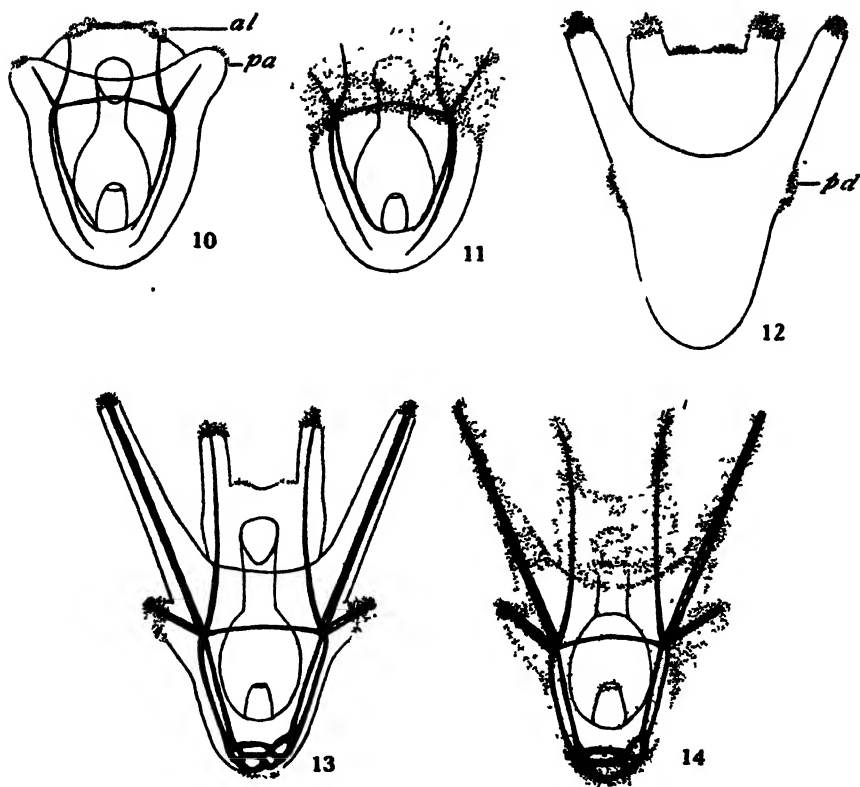


PLATE 18

Figs. 10-11. Two stages in the disintegration of a prepluteus, showing the regions of high susceptibility associated with the formation of the postoral arms (pa) and the antero-lateral arms (al), and also the apico-basal gradient in the body ectoderm.

Fig. 12. Early stage in the disintegration of a pluteus in  $\text{NH}_4\text{OH}$ , showing the regions of high susceptibility preceding the outgrowth of the postero-dorsal arms (pd).

Figs. 13-14. Two stages in the disintegration of an older pluteus, showing the gradients in the arms, the region of high susceptibility at the posterior end of the body and the beginning of obliteration of the gradient in the body ectoderm.

degree of physiological dominance between the preoral lobe and regions posterior to it becoming less and less marked in the later larvae.

Child (1915, 1916a) has also noted the disappearance of the gradients in the later larvae of the sea urchin and of the starfish, and has advanced the suggestion that it is this obliteration of the gradients and consequently of physiological dominance which makes possible the new gradients, and therefore the new axes of the adult. However it must be stated that at the present time we are quite ignorant of the external and internal relations which determine the origin and direction of the axes of the adult individual.

Finally attention must be called to the fact that these observations of the gradients in the developmental stages of the sand dollar are a repetition of Child's observations on the sea urchin, and that the evidence presented here shows that the axial relations in rate of metabolic activity are essentially the same in similar stages of the two forms.

I am deeply indebted to Drs. C. M. Child and L. H. Hyman of the University of Chicago for suggestions and for criticism of my work. I am also under obligations to Dr. B. M. Allen of the University of Kansas for material. The experiments recorded here were performed at the Puget Sound Biological Station during the months of June and July, 1920. I am indebted to the Director, Dr. T. C. Frye, for the courtesies of the Station during this time.

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## Some Reactions of the Jellyfish, *Aequoria*.

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### 1. INTRODUCTION

*Aequoria aequoria* Forskål, the medusa used in the following experiments, is one of the most abundant jellyfish found in the region of the Puget Sound Biological Station. At certain times, as, for example, during the latter part of July, 1920, when these studies were made, the animals were very abundant, but at other times almost none of the species could be found. In its natural habitat *Aequoria* is usually seen swimming near the surface of the water, and, in sheltered places, between logs of driftwood, etc., it usually comes quite to the surface. When kept in a jar in the laboratory its normal position seems to be at the surface, thrusting the tip of the bell out into the air at each pulsation. Very little experimental work has been done, previously, with this species, as the greater part of the work on jellyfishes has been done on *Gonionemus* and *Cassiopaea*. Child, however (1918) compared the susceptibility of *Aequoriae* of various sizes to acid, alkali, KCN, etc. As far as is known by the authors, no previous experiments with medusae have involved the use of gradients, except those performed by Morse (1906) with *Gonionemus*. He subjected the animals to a heat gradient, and found the optimum to lie between 20° and 30° C. Bethe (1909) studied the relation between hydrogen and hydroxyl ion concentration and rate of pulsation in *Rhizostoma*. Other publications with some bearing on the present subject are given in the bibliography.

All the animals used in this series of experiments were taken off the float at the Puget Sound Biological Station, most of the experiments being performed with animals taken the same day, altho in some cases animals were used which had been kept in running sea water in jars on the laboratory tables as much as two days. No differences in behavior were observed between the specimens kept in the laboratory for a few minutes or a few hours, and those kept one or two



days. In all cases only animals in seemingly good condition were used. In general animals of small size (3 to 5 cm in diameter) seemed to be most active and these were used in preference to full grown specimens. The reactions of the species, with reference to hydrogen ion concentration, salinity, temperature and currents of the surrounding medium were studied.

## 2. REACTIONS IN GRADIENTS OF THE pH OF SEA WATER

In the experiments involving the reactions of the animals in gradients of the pH of sea water, the gradient tank described by Shelford and Allee (1913) was used. The sea water was introduced into the tank by means of siphon tubes from reservoirs located about one meter above the tank, and the inflow was kept constant and equal at the ends of the tank by means of screw cocks. The rate of flow was kept very low (70 cc per minute from each reservoir), just sufficient to maintain the desired gradient in hydrogen ion concentration but not enough to produce an appreciable current. Frequent controls showed that this current, and other extraneous conditions, had no effect on the movements of the animals. The same temperature was maintained at the two ends. The gradient tank was carefully screened with blackened cloth and illuminated symmetrically by means of two candles, so that light would have no effect upon the results. The pH was determined at three places in the tank (at either end and in the middle) and these readings were taken at the beginning and end of each one hour experimental period, and occasionally at more frequent intervals. The indicator method described by Clark and Lubs (1917) was used. A series of buffer solutions was made up and checked against standard colorimeters manufactured by Hynson, Westcott and Dunning. Phenol red, thymol blue, and brom thymol blue were used as indicators. On advice and information received from Dr. E. B. Powers the pH values obtained in this way have been corrected for the salt error ( $-0.22$  for Puget Sound sea water), and all figures for pH values appearing in this paper have been obtained by subtracting the correction factor given above from the colorimetric reading. The variations in pH in the gradient tank were obtained by adding to the sea water in the reservoirs mentioned above, which varied in pH from 7.7 to 8.0, definite quantities of weak solutions of HCl or of  $\text{Na}_2\text{CO}_3$ , in sea water. The dilution occasioned by adding the acid or alkali was thus negligible. The current was allowed to run thru the tank for some time, until the gradient became stabilized, then the animal was carefully introduced near the middle of the tank and graphic records were made of its movements for the period of one hour. The results of representative experiments

are illustrated in plate 19, which shows the graphs of the reactions of five animals in various gradients of hydrogen ion concentration. The back and forth movement of each animal is drawn to a vertical time scale, divided into five-minute periods. The experimental period is in each case one hour. The spaces separated by the vertical lines at the top of each graph represent the thirds of the tank. The pH readings are shown at the top and the bottom of each space, the values given having been determined immediately before and after each experimental period.

1. In the experiment illustrated by graph 1 the pH varied from 8.2 to 8.5 and the animal very definitely sought the lowest pH available. The animal used in this experiment was small (3 cm in diameter) and was collected the same day as used. A tendency to swim in small circles became apparent after the twentieth minute of the experiment.

2. The pH here varied from 8.0 to 8.4 and the result was similar to that of the previous experiment. The animal was 3 cm in diameter and was obtained just before the experiment was performed.

3. Graph 3 illustrates reactions to a pH varying from 7.2 to 8.4 at the beginning of the period and from 6.7 to 8.4 at its close. This was a much steeper gradient than the first two shown. The animal tended to occupy the center of the gradient tank, at a pH of about 7.8. The diameter of this animal was 3.5 cm. It was collected the same day the experiment was performed.

4. In this case the pH varied from 6.4 to 7.9. The animal for the most part reacted negatively to the lower pH regions, but finally got into the 6.6 region, and sank to the bottom, upside down, pulsating weakly.

5. Reactions in a pH gradient from 7.9 to 8.1. The animal spent the greater part of the time in the 7.9 region.

These graphs, as well as some twenty others not illustrated, show in general that *Aequoria* tends to select sea water with a pH of about 7.9, that is, about the normal hydrogen ion concentration of Puget Sound sea water. There is a tendency, however, for animals reaching regions of considerably higher or lower pH to stop pulsating and come to rest, often at the bottom of the tank and in an inverted position, without being able to escape from the unfavorable environment. Such reactions are represented by a star (\*) in the diagrams. The character of this reaction became much more apparent in later experiments involving a progressive decrease in the H ion concentration of the water.

During the experiments in the gradient tank considerable attention was paid to the rate of pulsation of the animals in the different regions

of the tank. The number of pulsations per minute was recorded at frequent intervals, but these figures seemed to show no definite relation to the pH within the limits of pH 6.6 to pH 8.7.

### 3. EFFECTS OF SEA WATER OF VARIOUS HYDROGEN ION CONCENTRATIONS

a. Animals of approximately equal size were placed carefully into individual jars containing sea water to which had been added the requisite amount of HCl or  $\text{Na}_2\text{CO}_3$  to give the desired pH. Then the rate of pulsation was taken at intervals and the survival time of the different individuals was noted. The results are given in table 1.

TABLE 1

pH	Time elapsing before death	Pulsations per minute		
		After 0 Min.	30 Min.	60 Min.
6.8	Alive at end of Exp. (120 hrs.)	38	16	24
7.0	Twenty-four hours	36	16	12
7.2	Alive at end of Exp.	45	24	24
7.4	Alive at end of Exp.	43	30	27
7.6	Alive at end of Exp.	7	24	17
	Average	34	22	21
7.9	Control	30	20	35
8.0	Alive at end of Exp.	10	40	60
8.2	Alive at end of exp.	10	10	10
8.4	Twenty-six hours	23	10	36
8.6	Alive at end of Exp.	11	10	16
	Average	14	18	31

Temperature at beginning of experiment, 11°C; at end. 14°C.

From this limited number of observations there seems to have been little consistency in the variations in the rate of pulsation. The smaller numbers were mostly due to longer periods of rest and not to a lower rate of pulsation while active. If there was an effect it was in the opposite direction from that observed by Bethe (1909) for *Rhizostoma*. According to Bethe a decrease in the H ion concentration causes a slowing of the rate of pulsation and a decrease in pH causes an acceleration, between the limits of pH 5 and pH 10.

b. Animals of approximately equal size (5-7 cm diameter) and equal rates of pulsation were used in these experiments. Each was placed in a Mason jar filled with normal sea water, so arranged that water of a higher or lower pH could be introduced through a siphon tube reaching to the bottom, and the pH thus gradually changed. The source of the modified water was a large reservoir connected by a siphon to a two-quart Mason jar and provided with a pinchcock for regulating the rate of flow. Each two-quart jar contained, at the beginning of the experiment, unmodified sea water. From this mixing jar, the second siphon led to the one-quart jar in which the animal was kept. The arrangement of the control was the same except that the

water supply consisted of normal sea water unmodified by the addition of chemicals. The rate of pulsation was observed in experimental and control animals. Typical results are recorded in tables 2 and 3.

TABLE 2

Time in Min.	pH of Exp.	pH of control	Pulsations per minute	
			Experiment	Control
0§	7.9	7.9	58	50
1			45	
2			50	
3			50	
4			50	
5			45	49
10			48	49
11			50	51
13			51	40
15			50	50
17			52	38
30			54	40
33			44	42
36			50	44
39			46	40
42			50	40
43*	8.6	7.9	0	

Temperature, 11°C.

§ Before starting siphons.

\* At this point the experimental animal turned upside down, dropped to the bottom of the jar and ceased to pulsate.

TABLE 3

Time in Min.	pH of Exp.	pH of control	Pulsations per minute	
			Experiment	Control
0§	7.9	7.9	48	48
1			54	48
5			54	60
7			52	24
9			46	46
11			48	46
13			54	52
15			40	50
17			25	42
19			44	56
21*	6.4	7.9	0	

Temperature, 12.4°C.

§ Before starting siphons.

\* At this point the experimental animal turned upside down, dropped to the bottom of the jar, and ceased to pulsate.

These results indicate that a gradual change of pH from 7.9 to 8.6 or 6.4 does not alter the rate of pulsation of *Aequoria*, until the limits mentioned are reached, when pulsation ceases. Accordingly, in a longer series of experiments animals of approximately equal size were subjected to increasing or diminishing pH in the manner just described, and observations were made without counting pulsations. The pH at which pulsation ceased was noted. The results are given in table 4.

TABLE 4

Exp. No.	pH at which pulsations ceased	Elapsed time in Min. before cessation of pulsation	Location of animal	Remarks
1	8.9	47	top	
2	8.9	87	top	
3	8.8	87	top	at bottom 10th-15th min.
4	8.9	87	top	
5	9.0	107	top	at bottom 14th- 21st min.
6	8.7	87	top	at bottom 10th min.
7	8.8	87	top	
15*	8.7	36	top	
16*	8.7	42	top	
17*	8.8	50	.	
Average 8.82				
8	6.8	20	bottom	
9	6.8	10	bottom	
10	6.8		bottom	
11	6.5		bottom	
12	6.4	30	top	
13	6.6		bottom	
14	6.6		bottom	
Average 6.64				

Temperature, 11.5°C.

\* More rapid flow from siphons in these experiments.

It will be noted that in the alkali experiments animals became inactive when the pH reached approximately 8.8. If left in sea water at that hydrogen ion concentration they did not survive. However, if removed immediately to normal sea water, or if the pH of the medium was lowered gradually to 7.9, they recovered. The animals remained at the top in most cases. In the acid experiments the animals, at a pH of about 6.8, turned over, and, pulsating actively, proceeded to the bottom of the jar. Here, pulsation with the bell inverted was continued for some little time, but finally ceased before the pH had decreased much more. Animals were able to live for several days at a pH of 6.8.

#### 4. EFFECTS OF DILUTION OF SEA WATER

Animals of approximately equal size were placed in Mason jars, into which was introduced, by means of the apparatus described above, fresh water from the laboratory supply. Results of an experiment of this type are given in table 5.

TABLE 5

No. of Exp.	Grams per liter of NaCl when pulsations ceased	Elapsed time in minutes	Remarks
1	19.9	8	All turned over and moved downward, pulsating actively in inverted position for some time after reaching the bottom. After removal of fresh water siphon all revived and continued to pulsate in the inverted position at the bottom of the jar.
2	19.5	4	
3	18.0	9	
4	17.9	15	
5	18.0	22	
6	23.7	22	
7	25.6	22	
Average	20.3		

(NaCl content of normal Puget Sound sea water is 30.8 gms. per Liter.)  
Temperature 14°C

## 5. EFFECT OF CHANGE OF TEMPERATURE

a. The temperature of the water surrounding the animals was increased gradually by introducing warm sea water in the same manner as described above for other types of modified sea water. The animals sank to the bottom and ceased to pulsate as shown by table 6.

TABLE 6

No. of Exp.	Temperature at which pulsation ceased	Elapsed time in minutes	Remarks
1	24.0°	14	Animals revived when temperature was again lowered. Killed at 28°C.
2	24.5	15	
3	21.0	22	
4	24.0	10	
Average	23.4		

Temperature at the beginning of the experiment was 14°C.

b. A single medusa was placed in a jar containing sea water at 11° C., which was then placed in a vessel and packed in ice and salt. The results are given in table 7.

TABLE 7

Time in Minutes	Temperature of water in jar		Condition of animal
	bottom	top	
0	11°C	11°C	
10	6	7	Pulsating normally, at top
25	5	6	Pulsating normally, at top
30	4	5	Pulsating normally, at top
40	3	4	Pulsating normally, at top
45	2	3	Pulsating normally, at top
50	1	2	Pulsating, in middle of jar
110	-1	-0.5	Pulsating, in middle of jar
125	-2	-1	Pulsating, very slowly
135	-1.5	-1.5	Does not respond to mechanical stimulation
Jar removed and placed in sea water at 11°C.			
155	4°C	4°C	Pulsating normally

The results indicate that the animal is able to endure temperatures below the freezing point of water, for short periods, at least. The maximum temperature is surprisingly low, when one considers that *Aequoria* is found, also, in the warmer seas.

## 6. REACTION TO CURRENT

A single experiment was performed to determine the relation of *Aequoria* to current. The apparatus used was that described by Shelford (1917). Three individuals were placed in the experimental tank and three in the control. The current in the experimental tank was regulated so as to be as slow as could be obtained with the apparatus (8.7 cm per minute). The readings, showing the number of animals in each third of the tank, are given below (table 8).

TABLE 8

Time in Min.	Control			Direction of current	Experiment is to right		
	1	2	3		1	2	3
0	1	1	1		1	1	1
1	1	1	1		0	1	2
2	1	1	1		0	0	3
3	1	1	1		0	0	3
4	1	1	1		0	0	3
5	1	1	1		0	0	3

The animals were carried by this very weak current, so that, under ordinary conditions of tidal currents, etc., their powers of locomotion would be insufficient to remove them from an unfavorable environment.

Field observations indicate that when acted upon by tidal currents, *Aequoria* does not reach the surface, but drifts along at varying depths, as would perhaps be expected in an animal whose specific gravity is nearly the same as that of sea water. In quiet water the animal comes quite to the surface.

## 7. DISCUSSION

The time available was so short that it was impossible to follow to their logical conclusion the many lines of investigation suggested by these preliminary experiments on the environmental reactions of *Aequoria*. As mentioned above, this medusa, like many others, varies greatly in abundance at any one point. As shown by general observation as well as by the experiment just described, the animal is practically at the mercy of every current of any strength, and a great part of the variation in its distribution is probably due to variation in currents. That this is, in all probability, not the only environmental condition affecting the abundance of the animal at any point is suggested by the results of the experiments with variations in temperature, salinity, and hydrogen ion concentration. The animal could not, in the presence of a current of any magnitude select the optimum hydrogen ion concentration, but, if the pH should approach the danger point on the acid side, the inversion of the bell and the downward swimming reaction might very

well bring the individual into a more favorable environment. The same is true with regard to unfavorable conditions of temperature and salinity. This inversion was not noted, with any degree of regularity, in the experiments with high pH (alkalinity). The pH at which pulsation stops is, however, higher than any OH concentration ordinarily encountered in sea water. Powers (1920), however, found a pH as high as 9.3 in *Ulva* beds. The animal's reaction to extremes of acidity, high temperature, and lowered salinity might well be made the subject of further investigation. The reason for the inversion of the bell and downward swimming reaction, under these conditions we are not prepared to state at this time. Possibly the effect may be due to some other factor than those studied. In the case of the experiments with high temperatures and low salinity, lowering of the density of the medium might be the cause of such a reaction, but this could hardly be the case in the acid experiments. Further work on the subject, possibly involving the use of a vertical gradient tank instead of the ordinary horizontal one, might throw more light on this problem.

#### 8. CONCLUSIONS

1. In a gradient of pH *Aequoria* tends to remain in water having approximately the pH of Puget Sound sea water, that is, 7.9.

2. When the animal gets into water of a considerably lower pH, (higher H ion concentration) it often reacts by inversion, active movement downward, and later by a cessation of pulsation.

3. When subjected to water of gradually lowering pH the animal seeks lower levels at approximately 6.6. If water of more favorable pH is not found, pulsation soon ceases.

4. When subjected to water of gradually increasing pH pulsation stops at about 8.8. There is no consistently observed inversion and downward movement.

5. Within the limits named in 3 and 4, there is no consistent variation in the rate of pulsation due to change in pH.

6. Animals sink to lower levels and cease pulsation at a temperature of about 23° C.

7. A medusa subjected to a temperature of -2°C for a short time was able to revive after restoration to higher temperature.

8. When subjected to water of gradually decreasing salinity *Aequoria* exhibits inversion of the bell and seeks lower levels at a concentration of sea water corresponding to a NaCl content of approximately two-thirds that of normal sea water, or 20 grams per liter.

9. Field observations and a single laboratory experiment indicate that *Aequoria* does not react to currents of surrounding medium, but is carried about passively by them.



## 9. ACKNOWLEDGEMENTS

Our thanks are due to Dr. V. E. Shelford for suggestions and advice in carrying on this work, and to Dr. Shelford, Dr. F. W. Gail and the Puget Sound Biological Station for apparatus and facilities, and also to Dr. E. B. Powers for advice in regard to correction of pH readings for salt error.

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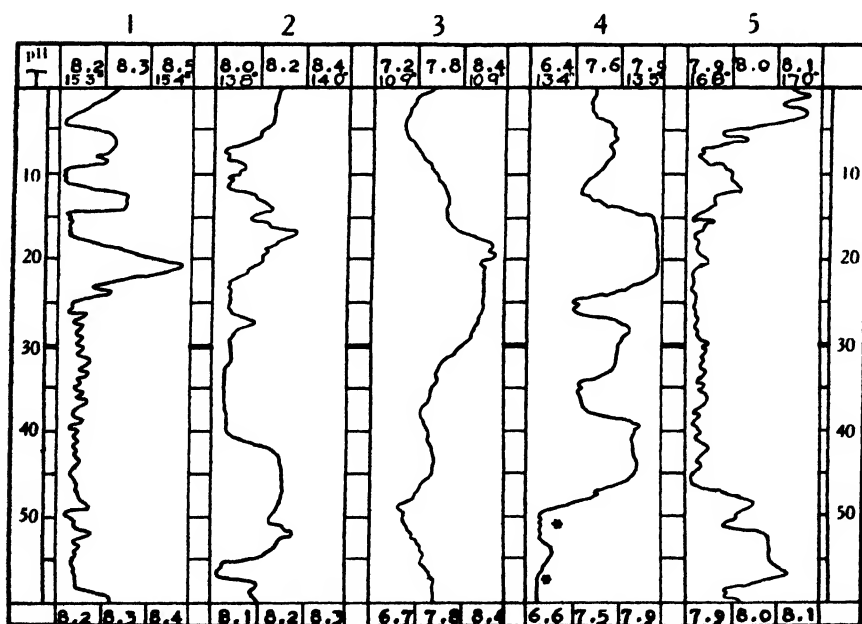


PLATE 19

This shows the reactions of *Aequoria* in a gradient of hydrogen ion concentration. The back and forth movement of each animal is drawn to a vertical time scale, divided into five-minute periods. The experimental period is in each case one hour. The vertical lines at the top of each graph represent the boundaries between the thirds of the tank. The pH readings are shown at the top and bottom of each column, and the temperatures at the ends of the tank are shown at the top. In graph 4, the two stars (\*) indicate places where the animal sank to the bottom of the tank and ceased to pulsate.





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## Announcement

The *Publications Puget Sound Biological Station* of the University of Washington appear at irregular intervals. The articles are numbered consecutively from the beginning of the Publications. The pages and plates are consecutive throughout a volume. The subscription price is \$3.50 per volume of about 400 pages. For information address Dr. T. C. Frye, University of Washington, Seattle, Washington.

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# **Preliminary Study of Methods of Examining the Life of the Sea Bottom**

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FRANCES MULLIS KIRSOP  
*University of Washington*

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## **INTRODUCTION**

We know of few attempts in American waters to gain accurate knowledge of the quantity of life per unit area of sea bottom. A systematic survey for quantity would likely lead to results as valuable as those secured by the Danish Biological Station at which extensive studies have been carried on. It was with the idea of making a beginning along such a line at the Puget Sound Biological Station that this work was undertaken in 1920. Naturally this preliminary work is largely a matter of apparatus and methods.

## **APPARATUS**

A bottom sampler, the invention of C. G. J. Petersen of the Danish Biological Station at Copenhagen, was used (Fig. 6). "On striking the bottom a clutch is released, and by hauling on the line, the apparatus is made to close \* \* \* \* about the section of bottom embraced, before it is lifted from the ground" (Petersen 1918, p. 5). This is only one of several types of samplers used by Petersen in his surveys of animal life in Danish waters and was intended for use on "hard bottom," which means hard clay, sand or gravelly bottom. Where the bottom is too stony or consists of stones or rocks, the bottom sampler is not effective (Peterson 1913, p. 22). However, in an attempt to gain some idea of the abundance of animal life on the sea bottom, the sampler was used not only on sand bottom but also on stony and rocky bottom.

The sampler was attached to the 178-meter cable of the Station boat. The cable was marked in 10-meter lengths, so that the depths could easily be recorded. The contents of the sampler was put into a sieve with 4 mm. mesh. In case of sand or mud bottom water was run through the sieve, to wash out the bottom material. With stony bottom, each stone was examined for animal life. Repeated samples bringing no bottom material showed the presence of clean rock bottom. The sampler tore some animals from the rock when they were present. Each

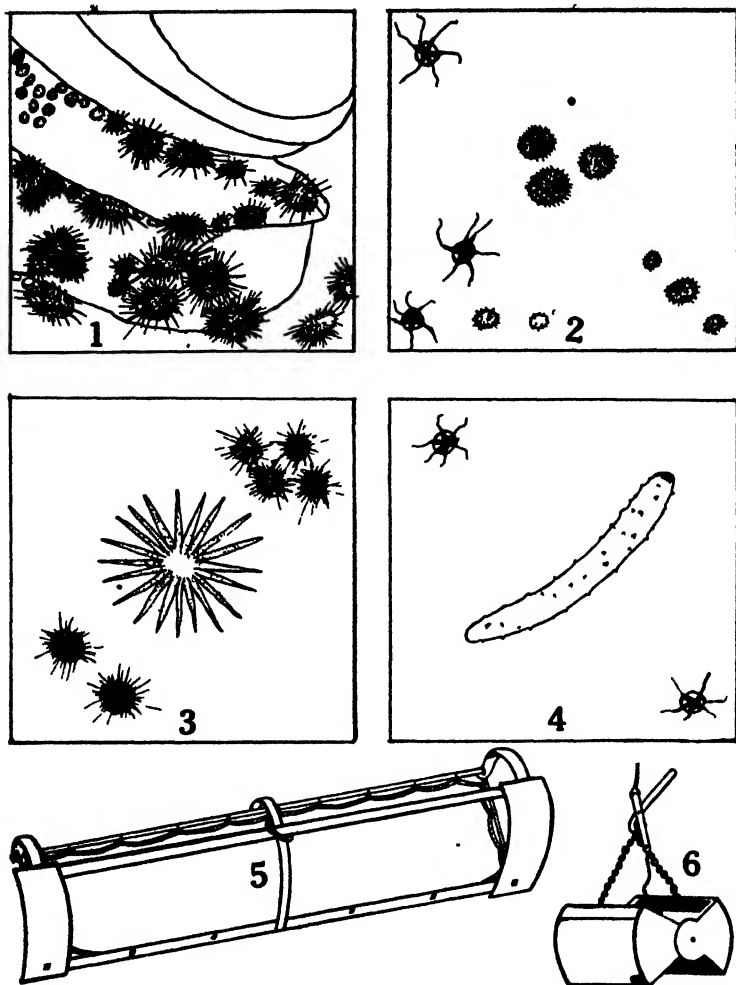


PLATE 20

Figures 1-4 are observations over ground on which sampling was done. Fig. 1, Distribution of the larger animals on one square meter; all sea urchins without spines are *Strongylocentrotus drobachiensis*; those with spines, *S. franciscanus*. Fig. 2, The same at three meters depth showing *S. drobachiensis* and three *Cucumaria japonica*. 3, The same at four meters depth showing *S. franciscanus* and *Pycnopodia helianthoides*. 4, The same at five meters depth showing *Cucumaria japonica* and one *Stichopus californicus*. Fig. 5, Cambridge (England) Biological Station rock trawl; this one was made according to sketches made by Prof. T. Kincaid. Fig. 6, The Petersen hard bottom sampler.

haul covered 0.1 square meter; 100 hauls covered 10 square meters. While sampling in 150 meters in San Juan Channel the sampler was lost. This reduced the amount to study with it.

The small dredge used in the work was the standard type, with a sharp strip of iron on either side to dig into the bottom; it was about a half meter wide, and was provided with a net bag with 13 mm. mesh. This dredge was usually drawn 20 meters so as to cover 10 square meters. The distance was estimated from lines of stakes set on shore, or by the captain of the boat through reference to shore points, so while it was not exact, it is undoubtedly about as accurate as any quick means of actual measurement. Short hauls were made so as to get the animals from as near the same depth as possible.

At the Puget Sound Biological Station the usual apparatus for obtaining bottom fauna has been a rock trawl about two meters long (Fig. 5). Its advantage lies in its ability to turn from side to side and thus avoid being caught on the rocks. When comparisons were made this was usually drawn 50 meters so as to cover 100 square meters.

#### METHODS

In work on sandy and muddy bottoms between the tide lines it is first of all essential to lay out contour lines beginning soon after the tide starts to fall. This can be accomplished by driving stakes at the water's edge, marking each 20 cm. fall in water level to low tide. This often requires one's presence at inconvenient hours. Less accurate results can be obtained with a carpenter's level and strong string. A stake is set at the water's edge and a strong string is tied 20 cm. above the water and the string leveled to the point on the shore 20 cm. higher. One square meter is then examined at each level to a depth of 25cm. and all animals secured, or if there is sufficient help, a trench may be dug from the lowest to the highest level. Table 1 shows the results of such an examination of the shore at Flat Point for bivalves.

TABLE 1. Showing the distribution of 4 genera of mollusks from low tide to 60 cm. above it (upper limit of livalves); number per square meter:

Distance in centimeters	0-20	20-40	40-60
Macoma, 3 species, mixed	32	19	7
Cardium corbis	3	9	3
Schizothaerus nuttalli	1		15
Mya arenaria			4

The Petersen hard bottom sampler was tested on sandy bottom at high tide in False Bay; and the day following, digging in the same areas showed a high efficiency (95%) for the animals which were on the surface and down to 25 mm. below. The rock trawl was put overboard following the sampling and secured none of the animals taken in the sampler. It operated like other trawls, securing only vegetation and animals on the bottom but not in it. Near Canoe Island, on a sand and mud bottom both rock trawl and bottom sampler were used. Twenty-five samples at depths of 15 to 22 meters were taken; the trawl was used over the same area, making 100 square meters covered. While more than one haul was taken, the one shown in table 2 is typical. Only one species appeared in both lots, and the number of animals per 10 square meters differed greatly. The number of animals collected is shown in table 2.

TABLE 2. Showing animals secured at 15-20 meters depth off Canoe Island on sand and mud bottom (no efficiency factor used):

Bottom sampler, 10 sq. meters		Rock trawl, 100 sq. meters	
Snails	4	Crabs	7
Small crustaceans	8	Shrimps	7
Worms	192	Hermit crabs	2
Bivalves	68	Bivalves	6
		Starfish	2
		Pectens	3
Total	272	Total	27
		Per 10 sq. m.	2.7

Among the animals taken with the sampler were 10 *Sternaspis* sp. otherwise not taken there. The use of more than one kind of apparatus is seen to be desirable. In Petersen's comparison of the dredge and the sampler over the same bottom, the same two facts stand out. "If the bottom sampler had been used over the whole area, it would certainly also have captured most the larger, 'rarer' animals which were taken by the dredge" (pp. 18-20, Rept. Danish Biol. Sta. for 1913). Of course, the rock trawl does not dig into the sand enough for one to form any opinion of the life there.

Later in the summer the small standard dredge was used to make hauls 20 meters in length at Flat Point on bottom varying from mud to coarse gravel. The animals obtained are separated into crabs and

shrimps, and less motile forms. This instrument secured a better variety than either of the other instruments (see table 3). The figures here used are the result of multiplication by 33.5, the factor for rock bottoms (see table 5). No animals less than 10 mm. in length or 5 mm. in diameter were counted in any case; as a rule 10 mm. was the limit. The numbers are in accord with other findings, for shrimps, crabs and small bivalves which gave the large numbers may be very numerous, but it is evident that this instrument is no more efficient on such bottom than on rock.

TABLE 3. Showing results at Flat Point with standard dredge at various depths, based on 10 square meters of bottom.

Depth in meters	1-5	6-10	11-15	16-20	21-25	26-30	31-40
Crabs, shrimps	33	100	2253	599	268	264	
Other animals	33	33	1946	969	1709	245	935
Totals	66	133	4199	1568	1977	509	935

Observations in shallow water over rocky and stony bottom were made at Point Caution. Here, below the tide lines, many sea urchin communities are noted (*Strongylocentrotus drobachiensis* and *S. franciscanus*). Other typical large animals are *Cucumaria japonica*, *Stichopus californicus* and *Pycnopodia helianthoides*, named in order of abundance. When looking into the water these are the principal forms one sees, though others are present, hidden by the vegetation or indistinct because of size or color (see Figs. 1-4).

The average efficiency of the sampler on rocks and on stony bottom was calculated at four stations on the northeast side of Brown Island. These stations were on the following kinds of bottom respectively: (1) Stony to gravelly with covering of *Fucus* and *Ulva*. (2) Large rocks covered with *Fucus* and *Ulva*. (3) Stony to rocky, lower *Ulva* zone. (4) Rocky, upper kelp and brown algae zone. Ten samples were taken at each place at high tide, then at low tide the animals per square meter were counted. All animals large enough to be seen easily, living on top of or under the rocks, or buried in the gravel, were counted. By comparing results the per cent of the total number of animals living on the bottom, which the sampler brought up, was determined (see table 4). The high per cent at station 4 may be due to under count; it was under water when counted, making accuracy difficult. Sometimes as many as ten samples at a station will fail to bring up a number of the animals. This was the case at station 3. The above results

TABLE 4. *Bearing on the relative efficiency of the bottom sampler on rocky stony bottom.*

Station numbers	1	2	3	4	Totals
Animals per square meter by count	123	76	70	49	218
Animals per square meter by sampler	19	12	5	15	51
Percent of efficiency	15.4	15.8	7.1	30.6	16.04

would seem to show that to obtain the average number of animals per square meter the number brought up by the sampler should be multiplied by six. The method employed makes the figures obtained by the use of the factor the mean total of all kinds of animals.

TABLE 5. *Showing relative efficiency of several forms of apparatus, on rock bottom, based on the animals per 10 square meters.*

Depth in meters	1-5	6-10	11-15	16-20	21-25	26-30	31-40	41-45	46-50	51-25
Bottom sampler										
No. of samples	4	13	14	18	8	4	28	15	10	18
No. animals per 10 sq. meters	125	353	42	255	76	325	161	77	170	106
No. corrected for sampler av. eff.	750	2118	252	1530	456	1950	966	462	1020	636
16% secured; factor 6										
Rock trawl										
Square meters covered			Over 66		Over 400				Over 20	
No. animals per 10 sq. meters			4.6		1.5				10	
2.28% secured; factor 43.8			2.57%		3.27%				1%	
Standard dredge										
Square meters covered; over	20	10	30	10		50		30	20	
No. animals per 10 sq. meters	20	39	8	10		6.6		2.2	2.5	
3% secured; factor 33.5		.92	15.4%	.47%	2.1%	.67%		2.17%	.32%	

Considering all collections on rock bottom, table 5 shows the efficiency of the instruments used. For rocky and stony bottom, the vicinity of Point Caution and about a mile northwest of the point, were the stations explored (Fig. 7). The shore in places is very steep, and consequently the sampler often came up empty or with very few animals; this may account for the few animals gathered from 11-15 meters and from 21-25 meters.

Most of the sampling done north of Point Caution was in 38-50 meters. Here the tide is very swift, hence the numerous bryozoans, barnacles and decorator crabs (*Scyra acutifrons*) in addition to the other life typical of rock shores. In giving numbers of animals the small colonial forms are not considered. The bottom consisted of solid rock, of stones, stones and gravel or coarse sand, and of stones and dead shells. Sometimes, specially a mile northwest of Point Caution,

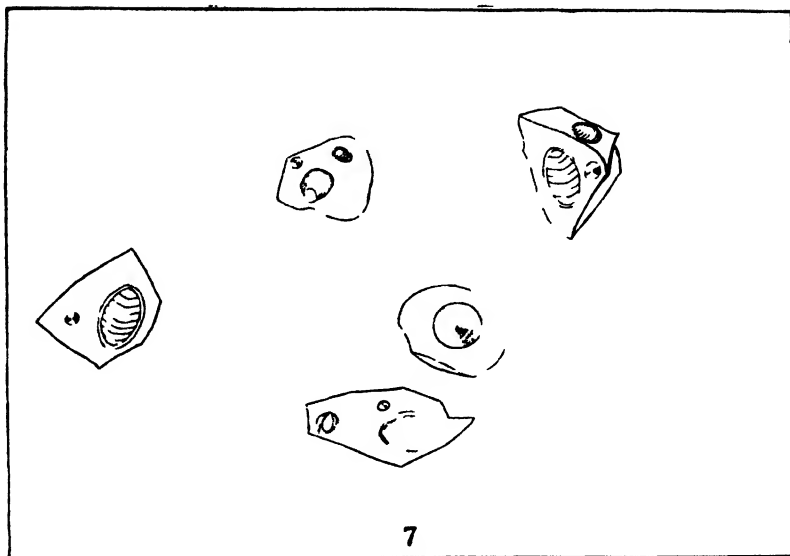


PLATE 21

Fig 7 One sample from stony bottom at eight meters, relative area covered by sampler is shown by boundary lines (27 x 37 cm)

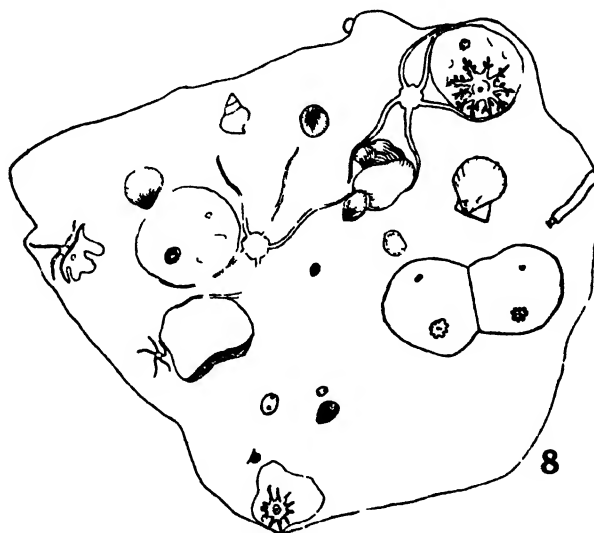


PLATE 22

Fig 8 A stone from 35 meters indicating 5600 animals per 10 square meters.



as much as a quart of bottom, consisting of either stones or shells, or both, would come up in one sample. At the latter station the stones were usually smoothed from water action, while off the Point they were nearly always angular.

One haul with the dredge at 38 meters brought up a rock that covered about  $1/20$  square meter and had 28 animals on it (Fig. 8). If this is a fair sample of the abundance of life on the sea floor at this depth, we should find 5600 animals per 10 square meters, without considering animals that live under the rocks unattached. In this locality at some points the bottom is muddy. Fig. 9 shows a typical sample from mud.

It is impossible from the work done, to characterize any animal community by any one or two typical animals, as Petersen did for the different bottoms in the Danish waters. There are at least two reasons for this: (1) The difficulty of keeping the boat in one place. This drifted with the tide or wind. Also, along a rocky shore the presence of ledges, and of crevices or depressions into which finer material can drift, may make two places only a few feet apart differ entirely in characteristic animals. The tides and winds may cause differences,

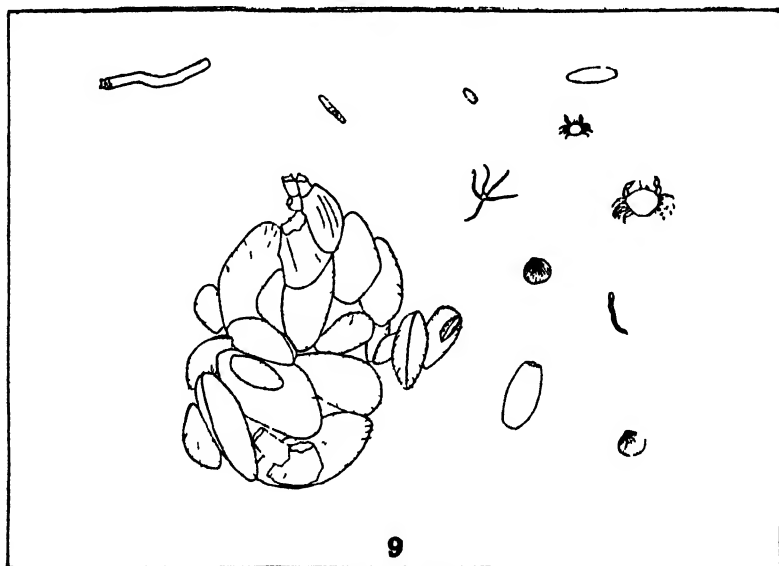


PLATE 23

Fig. 9. Sample from 125 meters, mud bottom, showing the area covered by the sampler and the animals present. It indicates 3900 animals per 10 square meters.

as they do in the inter-tidal zone where the contour of the shore can be seen. (2) The uncertainty as to whether the samples represent the most numerous species, or whether they just happened to be in a position for the sampler to pick them up. This resulted largely from the limited amount of sampling. However, in view of the fact that the sampling represents definite depths, beyond doubt, and the dredging is uncertain as to depths, a partial list of animals taken is shown in table 6.

TABLE 6. *Partial list of the number of individuals per square meter secured at various depths on rocky bottom with bottom sampler.*

Depth in meters	1-5	6-10	11-15	16-20	21-25	26-30	31-40	41-45	46-80
<i>Strongylocentrotus drobachiensis</i>	*30	186		36					
<i>S. franciscanus</i> Ag.	*42			36					
<i>Stichopus californicus</i> Semp	*3						42		
Brittle star						150	24		
<i>Calliostoma costatum</i> Mart		90	42	36			84	42	
<i>C. annulatum</i> Mart							24		
<i>Margarites lirulata</i> Cpr				36					
<i>M. papilla</i> Gld	150			168					
<i>Amphissa columbiana</i> Dall				168					
<i>Lacuna porrecta</i> Cpr				36					
<i>Acmaea mitra</i> Esch		186							
<i>A. patina</i> Esch		48							
<i>A. pelta</i> Esch	150	48		72					
<i>Crepidula dorsata</i> Brd		48							
<i>C. nivea</i> Adams		24							
<i>El-suridea aspera</i> Esch				36					
<i>Calyptraea mammillaris</i> Brd		600		168			66	84	
<i>Pecten herckeus</i> Gld				72					
<i>P. hindsii</i> Cpr									†
<i>Pododesma machoschisma</i> Desch		90	84	132	150		24		
<i>Semele rubropleta</i> Dall					78				
<i>Psaphidia lordii</i> Baird							24		
<i>Venericardia ventricosa</i> Gld.			42				42		
<i>Laphia staminea</i> Conr							66	42	
<i>Cardium californiense</i> Desch.							24		
<i>Leda</i> sp							24		
<i>Terebratella transversa</i>								42	
<i>Tubs worms</i>		186				300		84	
<i>Chitons</i>	300	186		132	150	1050	66		
<i>Barnacles</i>							84	42	
<i>Lophopanopeus bellus</i> Stlm				66			24		
<i>Oregonia gracilis</i> Dana				66			24		
<i>Paracrangon echinata</i> Dana							24		
<i>Scyria acutifrons</i> Dana						300	24		
<i>Hermit crabs</i>		228		66			108		
<i>Crangon munita</i> Dana			42						
<i>Pugetia gracilis</i> Dana	150	48	42		78				
<i>Cancer oregonensis</i> Dana				66			24		
<i>Spirontocaris grandimana</i> Broz.									6
<i>S. herdmanni</i> Wal.		48							
<i>S. kincaidii</i> Rath							42		
<i>S. prionota</i> Stlm.							24		
<i>S. pusilla</i> Kroy							24		
<i>Harpinia affinis</i> Holmes								84	
<i>Sea slug</i>				36					
<i>Nereis</i> sp.				36					96

\*Not secured with sampler; observed from row boat.

†Number not counted.

## DISCUSSION

The task of determining the abundance of animal life at depths that cannot actually be seen is difficult, but by no means impossible. The bottom sampler has many drawbacks, even for this work. In a half day one cannot count on taking more than 50 samples, or 5 square meters at a depth of 40 meters. On rocky bottom, where the sampler is only about 16% efficient, this means picking up the animals on less than one square meter. Since no sifting is necessary on rock bottom, much larger samples could be cared for, even by one person. Sufficient interest in the problem of abundance would undoubtedly lead to better apparatus. The picture the dredge gives of the sea floor is well expressed by Professor H. F. Jungerson, "That a dredging ship may be compared with an air-ship towing a dredge over Copenhagen, catching a policeman in one street and a perambulator in another, and from these it draws its conclusions as to the whole population of the town." Petersen adds, "The dredge has evidently been used as a sort of necessary evil because nothing better was known, either to replace it or even to use along side it, and I am quite willing to admit, that it has rendered great service to science but it would certainly improve by competition; I hope the bottom sampler will become a keen competitor of it, also out in the depths of the sea \* \* \* with the bottom sampler we obtain the common and generally distributed animals in or at the sea-bottom, with the dredge we get the larger and rarer animals, and finally with the large sea nets the still rarer and larger."

It is evident that a number of kinds of apparatus must be used over a given bottom to secure a representative collection. No instrument is really efficient on rock bottom, but though the sampler was not intended for such bottoms, even the limited sampling shows that it is far more efficient than a dredge or trawl. It appears to be of considerable advantage in determining the efficiency of other equipment, and a second advantage is shown by a comparison with the results of Perry (1916); the lower limits of forms occurring on shore and in the area covered with brown and green algae between 0 and 20 meters is extended by the sampling. The sampler may be dropped directly to the bottom in a small open space and animals secured. Under all conditions it has the advantage of giving absolute record of depth; on rocky bottom it is very difficult to know from what depth specimens come when secured in a dredge.

On sandy bottom the type of sampler used is very effective and probably gives exact result though it does not dip more than a couple

of inches into the bottom. Here it appeared to miss all of the crabs and other forms capable of rapid locomotion.

The problem of the productivity of the sea bottom is one which must be quite completely studied in connection with fisheries of all sorts. It is obvious that bottom samplers, dredges of all types, trawls, etc. must all be used, since each one picks out particular things, but bottom samplers are most efficient. With adaptation and modification along lines already undertaken by Peterson (1918), it will probably form the basis for quantitative work.

The estimates indicate between 252,000 and 2,118,000 animals (with longest dimension about 10 mm. or more) per hectare (101,590 to 817,142 per acre) on rocky bottom; from 66,0000 to 4,199,0000 per hectare (26,709 to 1,699,312 per acre) on sandy-gravelly bottom; and 3,900,000 per hectare on deep water mussel beds. Such estimation is one of the several steps necessary in determining the productivity of the sea bottom in fish food.

#### ACKNOWLEDGEMENTS

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# **A Study of Light Penetration Into Sea Water Made With the Kunz Photo-Electric Cell With Particular Reference to the Distribution of Plants.**

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## I. INTRODUCTION

The intensity of light at various depths in water is significant because the energy involved is important to photosynthesis and because the blue end of the spectrum is stimulating to the growth and movements of marine animals and variously affects the growth of plants (Davenport 1899). The photo-electric cells of the type used (Kunz's K-H) are fortunately most sensitive to wave lengths  $.42\mu$ -. $50\mu$  and with extreme sensitivity from  $.43\mu$  to  $.47\mu$ .

## II. GENERAL METHODS

The study of the penetration of light into water has usually been conducted with the use of Secchi's disk or with sensitized plates or paper. There is a single set of readings with a selenium photometer by Regnard.

1. *Secchi's disc.* This is a white disc 20 cm in diameter. It is lowered and the depth at which it disappears and reappears again are noted. The mean between them is used as an index of light penetration (Needham and Lloyd 1916).

2. *Photo-chemical methods.* Various methods of exposing photographic plates and paper have been used. Regnard used a sensitized paper on a drum turned before a slit by clock work (Fig. 1). The Michael Sars (Murray and Hjort 1912) carried a Helland-Hensen Photometer. This apparatus consisted of a frame with two side bars on which a plate holder and cover might slide when released. The plate holder was nearly cubical, slightly smaller at the top and carried plates on four sides and at the top. The cover was a box of similar form which fitted tightly over the plate holder. The plate holder and cover were latched in place at the top of the frame at the time the instrument was lowered. The first messenger released the plate holder which dropped to the bottom of the frame exposing the plates. The second messenger dropped the cover to the bottom covering the plates and ending the exposure. Light penetration was demonstrated with this apparatus down to 1000 meters. On June 6 at  $31^{\circ}15'$  N. Lat. in the Atlantic Ocean the plates showed distinct light effects after an exposure of two hours at 1000 meters. When lowered to 1700 meters and exposed for two hours no changes were noticeable in the plates. The observers came to the conclusion that light penetrates to a depth somewhere between 1000 and 1700 meters. This photometer is one of the latest and best types of instruments for the use of sensitized plates or papers. Grein (1913) found light at 1500 meters.

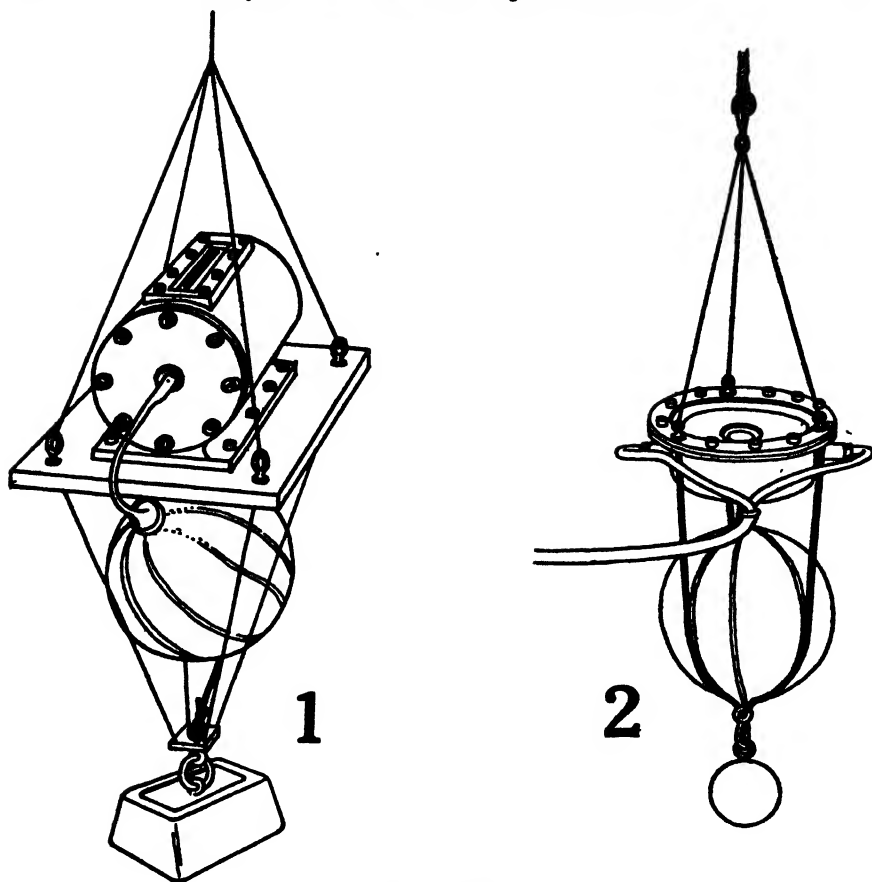


PLATE 24

Fig. 1—Regnard's photographic paper photometer, in which the paper was turned in front of a slit by clock work. Note the rubber sack to equalize inside and outside pressures.

Fig. 2—Regnard's selenium photometer.

3. *Selenium.* One attempt has been made to use the Selenium cell. Regnard in 1889 made a series of determinations of light penetrations in the harbor at Monaco using a Selenium cell (Fig. 2). The galvanometer on which the readings were made was located in the laboratory of the Prince of Monaco, and the cell was lowered into the harbor by means of a long cable. He states none of the difficulties nor precautions connected with the work. Selenium cells are commonly made by connecting several narrow strips of light-sensitive Selenium parallel between the edges of two brass plates. The resistance of such a cell depends upon



the construction and the treatment of the Selenium. It is very difficult to make duplicate cells. In general the higher the resistance, the higher the sensitivity, that is, the greater the ratio of its conductivity in the light to its conductivity in the dark. Some high resistance cells show a conductivity change of 20,000 per cent (200 times) when taken from direct sunlight into a dark room. The amount of change of conductivity is the function of the time of illumination, the temperature, and the character and intensity of the light. The cell must be operated at a constant temperature or correction must be made. If a strong light is suddenly thrown on a high resistance cell, the resistance decreases to a minimum in a fraction of a second, then slowly begins to increase again. Generally a stable value will be reached after a few minutes but this value is not always well defined. Most cells increase in resistance with a decrease in temperature. Hence, when lowered into the water the effect of the usual lower temperature at a greater depth would tend to exaggerate differences between readings at a given depth and at the surface.

4. *Pyrlimnometer*. This instrument measures the energy of the light entering the water. It consists of a receiver containing 20 small thermocouples which can be lowered into water to any desired depth down to 10 meters and alternately exposed to the sun and covered. The electrical effect of the sun's radiation on the thermocouples is proportional to the sun's radiation (Birge and Juday 1921). The energy in the blue end of the spectrum is very low and accordingly such determinations should be accompanied by a study of short wave length penetration.

5. *Photo-electric cell*. This cell (Fig. 3) has been developed through a series of stages. All metals emit electrons under the influence of light. This emission depends upon the kind of metal, upon the condition of the surface and upon the surrounding conditions. In most cases the emission is almost imperceptible. By using a very active metal such as sodium or potassium and placing it in an atmosphere of helium, hydrogen, or argon the photo-electric effects become very considerable. If the active material is mounted in a vacuum the temperature and other surrounding conditions have no effect on the current but the current is proportional to illumination only over a small range. If the cell contains a gas such as argon, the current will be proportional to the illumination up to about a hundred foot-candles. The number of electrons emitted is proportional to the intensity of the light and the photo-electric effect

of these cells is greatest in blue. The cells used were two Kunz cells made of extra heavy glass and tested for 40 atmospheres hydrostatic pressure. They were potassium-hydrogen cells. On account of the pressure to which it was expected to subject them they were made small. Heavy glass rendered construction somewhat difficult so they were only a little over half as sensitive as some of the larger lighter cells made by the same investigator.

### III. METHODS OF MOUNTING CELLS

The question of mounting a photo-electric cell so as to prevent all contact with moisture is a serious one. The portion of the cell which is coated with potassium must be connected to the negative pole of a high voltage battery of from 80 to 160 volts. To secure perfect insulation at these terminals with these high voltages was difficult.

1. *The cable.* The cable used was 123 meters (400 feet) of saturated braid okonite, the so-called brewery cord or packing house cord, which consists of an outer cotton cover thoroughly tarred over a high grade rubber cover surrounding two cotton and rubber covered No. 18 flexible cords. This insulation is supposed to withstand sharp kinking, tying into knots, etc. A box was constructed and a piece of garden hose was slipped over an iron pipe nipple which was threaded through the wooden box. The cable was first pulled through an opening in the wooden box which was to be used to embed the cell. The lower end of the cable used was successfully closed to sea water as shown in figure 5 in which (a) and (b) represent the outer walls of the cord. At the point d, after the cable was cut, the rubber jacket was split back for a distance, the cotton covering of the two cords soaked with benzine, covered with rubber cement and a quantity of Goodyear tire putty (d) stuffed into the lower end of the jacket. A piece of the jacket was then folded between the two wires and while covered with rubber cement was wrapped with fraction tape. The wires were clamped under two porcelain cleats and a temporary box constructed about the terminal; pitch from two dry cells was then poured over the ends. The nipple and garden hose were poured full of vaseline. The cable was attached to the cell terminals by means of small coils of fine copper wire. When finally successfully embedded, the vaseline completely surrounded the end of the cable. It was lowered to 120 meters and subjected to 168 pounds per square inch but there was not the slightest evidence of any water having gotten into the outer jacket at the close of the summer's work. Thus the dry cotton goods and the layer of dry air which

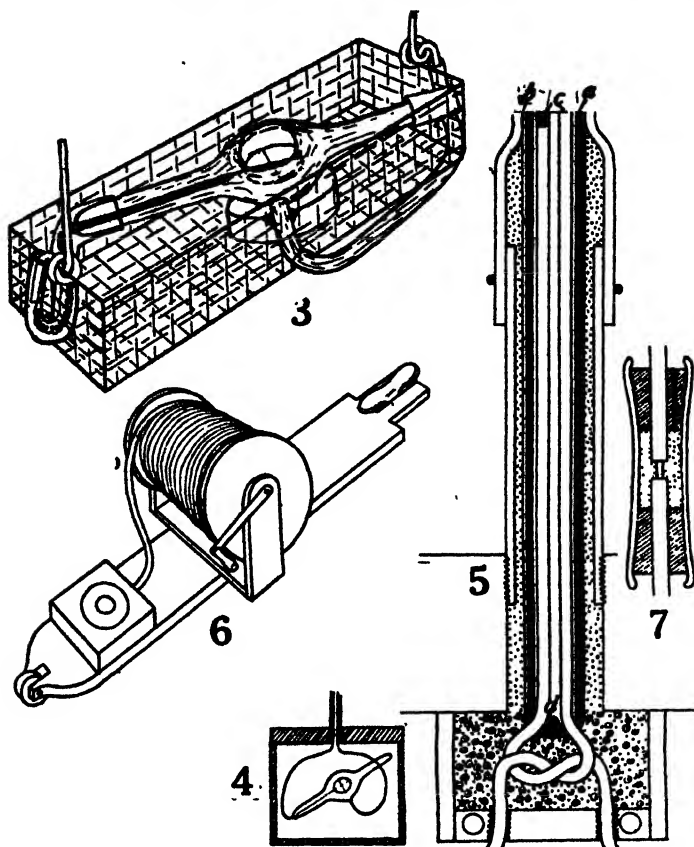


PLATE 25

Fig. 3. A photo-electric cell with terminals covered with rubber tubing, insulated wires inserted and the rubber tubing filled with vaseline. This was successfully used in shallow water.

Fig. 4. Showing the photo-electric cell in position in wooden box with wires indicated.

Fig. 5. Showing the method of closing the cable: (a), outer cable cover in; (b), rubber covering; (c), rubber and cotton covered cords which were closely twisted together; (d), rubber plug closing lower end (Goodyear Tire Putty); stippling indicates sealing wax and insulating pitch (dots surrounded by rings) covered with amber vaseline.

Fig. 6. The reel from which the cell was lowered.

Fig. 7. Showing a successful splice of paraffined ordinary lamp cord; soldered wires; two rubber stoppers, a piece of soft rubber tubing, and vaseline coupling the insulation. This was used in 10 meters of water without leakage.

separated the individual rubber-covered cords from the rubber jacket, constituted an excellent insulator. Plain rubber covered wires with an exposure such as we had would permit current to leak through the rubber. We were quite confident that such leakage under these conditions was essentially negligible. One difficulty which we experienced in connection with the cable was the fact that air occurred among the individual wires of the cord and was forced out under high pressure causing contact with sea water in some of our earlier efforts.

2. *Embedding material.* It was first thought that we could embed the cell by filling the prepared box with paraffin. This was done; and when lowered into water drowning and leakage occurred after only a few minutes. Various mixtures of Venetian turpentine bees wax, sealing-wax and paraffin were then substituted without success. Finally clean vaseline was used; this is sufficiently plastic to push into any vacant spaces and to permit the air to escape. Some of this vaseline was poured over paraffin left in the bottom of the box and on examination after exposure to high pressure it was found that where air bubbles had escaped from the paraffin the vaseline had been pushed into the cavities which they had occupied. In some cases the small cavities were completely filled with vaseline, and in others with a mixture of vaseline and sea water. Vaseline mixed with even very small quantities of harder substances such as paraffin, bees wax, or Venetian turpentine were not sufficiently plastic and water came in contact with the wires when anything else was used. Some of the vaseline after being kept in sea water for three months was tested by inserting the terminals of an 160-volt battery into it with a galvanometer in series. The galvanometer with a sensitivity of 80 megohms showed no deflection when two wires were inserted into this vaseline at a distance of 1 cm from each other. Similar tests of vaseline which had been used to embed the cell and melted and remelted showed the same result.

#### IV. METHOD AND CONDITIONS OF READING

1. *Condition of accuracy.* The photo-electric cell passes no appreciable current from a high voltage battery in the dark, hence the galvanometer used in the reading must come to zero when the cell is tightly covered. Hence before each reading the cell was covered and the amount of deflection if any noted. In case of no deflection the apparatus was lowered, readings taken, and the cell brought back on deck and covered. If it came to zero when covered the second time the readings were regarded as correct. This

is essential to successful use of the photo-electric cell especially in deep water or weak light. If the instrument does not come to zero when the cell is darkened, leakage of current is usually the cause, and the trouble we experienced was usually located in the connections between the end of the twin cable and the cell terminals, but sometimes on deck. A steady boat and clear sky are essential.

2. *The Boat.* A ten-ton steam boat was used for most of the work. On the enclosed waters of Puget Sound this was fairly satisfactory, but a 10-ton scow towed by a ten-ton gasoline boat, with pilot house control, was steady and generally better, as it was quickly and easily managed. A larger vessel would be needed for work outside of such quiet waters.

3. *Lowering the apparatus.* A wooden drum 19 inches in diameter was used as a reel for the cable. The cell was attached to a trawl frame which was in turn attached to the trawl cable, which was calibrated in meters with variously colored paints. The cell was ordinarily raised and lowered by means of machinery on the vessel, the electric cable being run out a distance equal to that which the steel cable was let out. On one occasion, however, the cell was lowered on a small triangular dredge frame, the weight being borne largely by the electric cable itself, and a cotton sounding line was used to give distance. This proved entirely satisfactory in deep water, but judging from experience in shallower water the heavy equipment is apparently desirable on account of liability to strike rocky bottom. A second cell similarly embedded and used on about 12 meters of electric cable, was lowered by hand with a 15 meter rope marked in meters. At times when the sky was variable one cell was read on deck and the other at a distance below the surface. This aided in detecting leaks.

4. *Method of reading the photo-electric current.* There appeared to be no suitable potentiometer on the market. As a result of experiments undertaken to make possible the use of a Leeds and Northrup Resistance Thermometer Recorder in recording sunlight, a modified resistance thermometer bridge or temperature indicator was used. In order to make the reading with this, a coil with the resistance of a platinum thermometer at 120°C. (the maximum range of the indicator) was placed across the posts to which the thermometer was ordinarily attached, so that with the slide wire turned to the 120 mark, the galvanometer stood at zero regardless of the battery potential. The battery potential of the bridge circuit was a dry cell, a potentiometer, and slid-

ing contact so that the potential on the bridge could be set at any desired point. For most of the readings either approximately 7, 21, or 35 millivolts were used. It was found that 7 millivolts gave a deflection of one galvanometer unit with the calibrated slide wire turned to  $-20^{\circ}\text{C}$ ; 35 millivolts gave five deflections under the same conditions. The potential was very frequently checked, with the photo-electric cell disconnected and also checked on the same millivolt meter. Figure 8 is

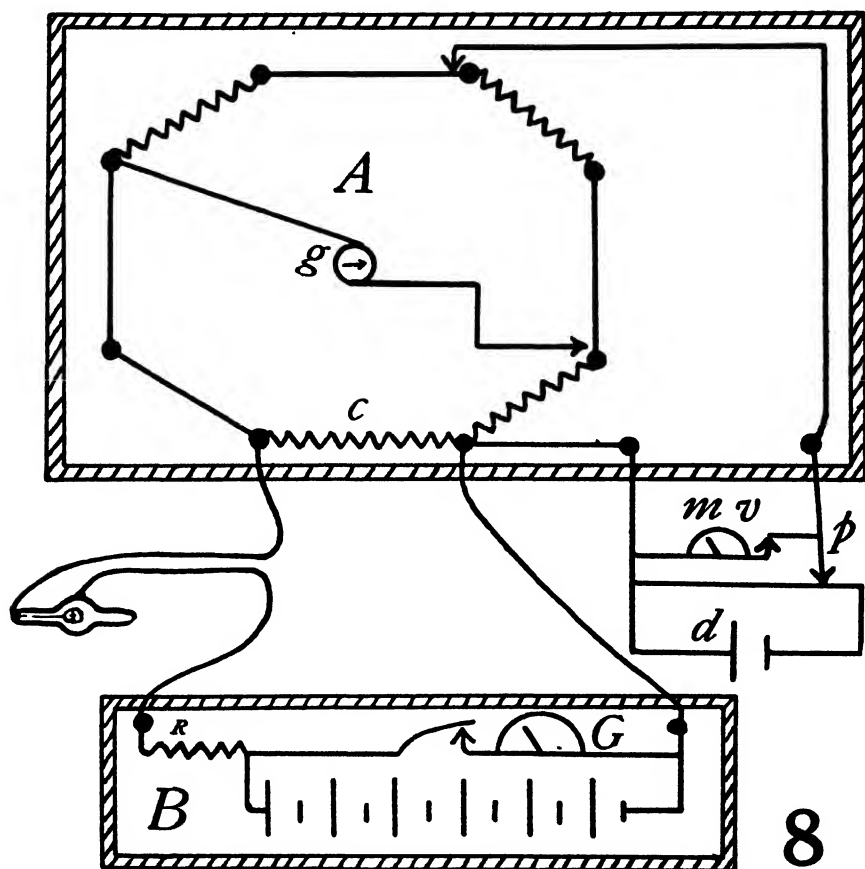


PLATE 26

Fig. 8. Showing a diagram of the balanced bridge, dry cell, photo-electric cell, and high voltage battery used. (A), The temperature bridge with galvanometer ( $g$ ) and two slide wires; (c), coil with the resistance of a platinum thermometer at  $120^{\circ}\text{C}$ .; (d), dry cell; (p), potentiometer; (mv), millivolt meter. (B), 158-volt battery. (G), High resistance volt meter. (R), Marconi 2-megohm resistance.

a diagram of the wiring of the potentiometer, of the bridge circuit, and of the method of connecting the photo-electric cell. No attempt was made to explain the behavior of the temperature bridge. The plan is complicated and accordingly a series of readings were taken with known potentials on the bridge circuit and known potentials in place of the photo-electric cell. With a low resistance galvanometer in series the headings and the calculations from the known potential showed the number of microamperes corresponding to the various readings on the calibrated slide wire. These were then plotted and all readings reduced to current. In other words the bridge was calibrated for current. These readings made at the University of Illinois after the work was finished, corresponded with a number of parallel readings made at the station on the temperature bridge and a galvanometer with a sensitivity of 42 meg ohms, with a resistance of 100 ohms, and a  $25\frac{1}{2}$ -ohm shunt. The current shown by this galvanometer was essentially the same as that found for corresponding readings at the University of Illinois. About half of the readings used in the cell calibrations were made with the potentiometer and bridge and half with the galvanometer used directly.

5. *Calibration of the Cell.* The two cells used appeared to be very nearly alike in sensitivity. In general the parallel readings on them were identical. The cell used for the deep water work was shipped to the University of Illinois and calibrated by means of a series of parallel readings with the Macbeth Illuminometer. The illuminometer measures the illumination of a special white plate. In sunlight a screen shutting out considerable of the blue is used. Since the eye is most sensitive to yellow (see Fig. 10) a very large series of readings of daylight were made. It was found that the current intensity curve is not a straight line beyond about 968 meter-candles but that the amount of current falls off rapidly so that the current-light intensity curve approaches closely to a straight line when plotted on semilogarithmic paper. Beyond 968 m.c. (90fc.) intensity is empirically expressed as

$$\frac{y}{k} = \log \left( 1 + \frac{x}{2000} \right) (10.763); \quad y \text{ is current in microamperes; } k=28.7;$$

$x$  is light in units which may be defined as short wave length intensity in one foot-candle of average sunlight (see Fig. 10).<sup>\*</sup> Because the instruments used were calibrated in foot-candles these units were used and the results reduced to meter-candles by multiplying by 10.763. Dropping this factor from the formula above gives foot-candles.

6. *Declination of the sun, refraction by water.* The declination of

TABLE 1. Showing approximate angle of sun's rays to perpendicular (zenith distance).

		A. M.												P. M.				Sun set
		VI.																
Sunrise		8	9	10	11	12	1	2	3	4	5	6	7					
July	18 4:10	....	....	....	28	27	28	....	....	....	....	....	....	....	....	....	8:03	
"	19 4:11	....	....	34	37	28	28	37	48	54	68	....	....	....	....	....	8:06	
"	23 4:16	....	....	....	45	27	30	28	30	37	48	....	....	....	....	....	7:58	
"	28 4:19	....	....	....	45	38	31	28	31	38	48	....	....	....	....	....	7:53	
"	36 4:20	....	....	....	46	28	31	29	31	38	48	....	....	....	....	....	7:53	
"	27 4:22	....	....	....	47	38	31	29	31	38	47	....	....	....	....	....	7:43	
Aug.	1 4:28	66	66	66	38	30	38	39	48	56	66	77	86	77	86	77	7:38	
"	2 4:30	66	66	66	38	30	38	39	48	56	66	77	86	77	86	77	7:34	
"	3 4:31	66	66	66	38	30	38	39	48	56	66	77	86	77	86	77	7:35	
Aug.	1 - 3																	
Angle in water		48.8	48.8	48.8	34.4	36.1	32.8	32.	32.8	36.1	34.4	36.8	43.8	46.	46.8	46.8		
Secant		1.89	1.43	1.37	1.88	1.83	1.81	1.80	1.81	1.83	1.88	1.87	1.83	1.87	1.83	1.83		



the sun for the dates on which readings were made, which ranged from July 18 to August 3, was ascertained by the use of a globe. The deviation of the sun from the perpendicular on these dates is shown approximately in table 1. Using the refractive index of water an attempt was made to determine the approximate angle which the light rays took or would take if the water surface were smooth. It is the opinion of several physicists consulted, that with the entire water surface flooded with light, such an assumption is the only one that can be made. The waters about Friday Harbor are remarkably smooth and only the smoothest days were used. The refraction of the water tends to bend the light to a more nearly vertical direction. Figure 9 shows the relations of the sun to the water surface at the different hours. The refracted path of a ray of light is shown with appropriate lettering. In calculating the angles, a table of natural sines and cosines is needed. The refractory index of water is about 1.333, which means

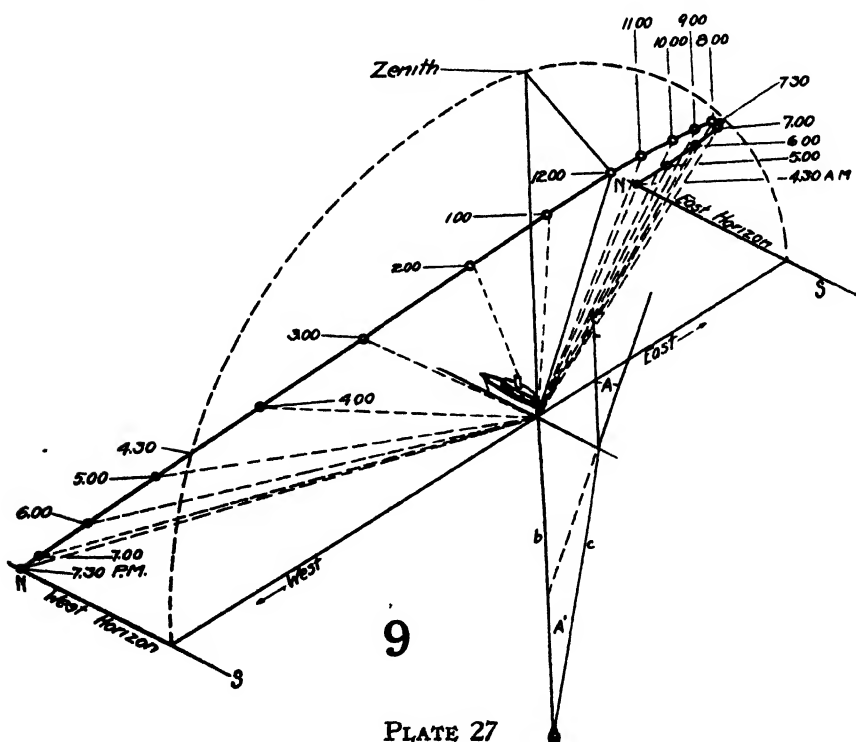


PLATE 27

Fig. 9. Showing the path of the sun (heavy line with small circles) on Aug. 1, 1920. The angle corresponding to  $A$  was determined, and the value of  $A'$  and the distance  $c$  calculated for all readings used.

that  $\frac{\sin A}{\sin A'} = 1.333$  (see Fig. 9). It follows that  $A'$  is an angle whose sine is  $\frac{3}{4}$  the sine of  $A$ . To make use of the table of natural sines it is well to bear in mind that in the case of a right triangle,  $\sin A = \cos (90 - A)$ , and  $\cos A = \sin (90 - A)$ . In the calculation of the light path per meter of depth, the fact that  $\cos A' = \frac{b}{c}$  was used and  $b$  taken to equal 1 meter vertical and  $c$  the oblique distance (see Fig. 9). Hence  $c (\cos A') = 1$ , or  $c = \frac{1}{\cos A'}$ . Some typical and average results are shown in table 2, in which the location, date, sun time, the sun's zenith distance

TABLE 2. Showing typical changes with increase in depth (Point Caution, Friday Harbor).

Sun time	Sun's zenith distance		Distance penetrated	Depth	Arbitrary scale reading	Microamperes	Light units, blue in candle's sunlight	Percent above surface	Percent below surface	Percent transmitted	Percent transmitted
	Alr	Water									
						f c	m c			M = 1.10	M = 1.00
10:13	37°	26°50'	Covered	0	0	0					
10:16	37°	26°50'	0 M	Dry	61.3	24.0	11,400	122,608	100		
10:17	36°	26°10'	0 "	Wet	57.8	22.4	9,800	108,677	86	100	86.0
10:18	36°	26°10'	1.11"	1	40	15.4	4,800	51,685	48.1	48.9	52.4
10:20	36°	26°10'	2.22"	2	36.3	14.0	4,000	43,052	35.1	40.8	54.6
10:22	35°	25°29'	3.30"	3	32.4	12.5	3,400	36,394	29.6	34.7	66.2
10:24	35°	25°29'	4.40"	4	31	11.9	3,180	34,226	27.9	32.4	64
10:26	35°	25°29'	5.50"	5	28.7	11.0	2,800	30,136	24.6	28.6	60.0
10:28	34°	24°48'	6.60"	6	27.2	10.4	2,560	26,553	22.5	26.1	61.8
10:30	34°	24°48'	7.70"	7	25.3	9.8	2,000	21,526	17.8	20.4	60.0
10:32	34°	24°48'	8:80"	8	21	8.0	1,800	19,373	15.8	18.3	60.8
10:34	34°	24°48'	9.90"	9	17	6.8	1,580	14,862	12.1	14.1	76.6
10:36	33°	24° 6'	10.90"	10	15.2	5.7	1,180	12,700	10.3	12.	86.5

or deviation of the light rays from the perpendicular, the distance through which the light had to pass to reach the instrument, the vertical distance, the reading, the current, and foot and meter candles are shown. The per cent at each level, the per cent of light transmitted by each 1.1 meters (the mean between the first reading, 1.11, and the last, 1.09)

through which the light must pass with each meter of depth, and the per cent transmitted through each meter are also shown.

## V. PRESENTATION AND DISCUSSION OF RESULTS

1. *Intensity of sunlight.* Table 3 shows relative intensity of sunlight and other light intensities taken chiefly from the Smithsonian

TABLE 3. *Relative illumination intensities, from the Smithsonian Meteorological and Physical Tables (1918).*

	m.c.	f.c.
Zenithal sunlight -----	100,000	8,000
Sky at end of civil twilight -----	265	33
Sky at sunset -----	4.30	.60
Zenithal full moon -----	.021	.02
Starlight -----	.00008	.00008
Visibility to eye at 1855 meters which is $10^{-12}$ sunlight----	8.00	.07

Tables. The eye can distinguish stars the light from which is about .000,000,000,000,1 of full sunlight (or full sunlight  $\times 10^{12}$ ).

2. *Light units at different depths.* Light units at different depths

TABLE 4. *Showing light intensities in meter candles and the equivalent in foot candles at different depths.*

Depth Meters	Mean all readings		Mean N/ read- ings	Maxi- mum	Aug. 1						
	f.c.	m.c.			123 volts			158 volts			
1	2	3	4	5	6	7	8	9	10	11	12
0 Day	8,680	63,100	110,300	187,300							
0 Wet	6,860	70,800	96,180	161,370	136,870	Do.	Do.	Do.	Do.	Do.	
1	8,400	86,120	66,360	117,110							
2	3,960	48,620	51,100	86,070							
3	3,140	33,780	40,300	64,520							
4	2,990	28,630	38,880	60,840							
5	1,990	21,480	34,100	51,560							
6	1,630	17,440	20,000	46,170							
7	1,397	15,030	16,860	41,360							
8	1,190	12,800	13,670	34,640							
9	990	10,680	10,670	28,960							
10	880	8,630	8,826	21,430	10,010*	16,140*	11,620*	13,990*			
20	335(8)	3,660	.....	3,900	1,020*	3,440	3,660	3,920	3,497	3,440	3,660
30	300(8)	3,817	.....	2,970	.....	.....	1,940	2,080	2,130	2,580	2,387
50	120(8)	1,300	.....	1,000	.....	1,890	1,190	1,890	1,960	1,722	1,841
75	74(4)	790	.....	860	.....	.....	.....	810	807	785	730
100	50(4)	480	.....	480	.....	.....	480	480	376	376	376
120	100(4)	120	.....	320	.....	.....	.....	300	60	60	60

\* Figures starred (\*) are not included in the averages. Further, the following readings were made but not included in the table: 10 M. 18,091 m.c.; 15 M. 5,700 m.c.; 20 M. 2,680 m.c. In columns 2 and 3, 16 readings are averaged in 1 to 10 meters; in deeper water the number of readings averaged is given in parenthesis in column 2.

in Puget Sound waters are shown in table 4. The second and third columns give foot-candles and meter-candles: these are the means of 16 readings taken meter by meter from the surface to 10 meters. The 93,100 meter-candles for the averages through approximately 1.28 air masses as compared with 103,324 meter-candles for one air mass (i.e. with the sun at zenith) speaks well for the calibration, especially in view of the small number of readings made on selected clear days. The means of the eight series of readings taken on specially clear days near noon serve to indicate the differences which occur from day to day. All of the 16 series of readings were made between 10 a.m. and 2:30 p.m. except three which fell between 2:30 and 5:00. The maximum readings shown in column 5 are largest at each level taken regardless of time or place. This series seems almost unreasonably large but indicates the variability of blue radiation. The Case cell calibrated entirely independently shows still higher readings (see circular published by Mr. Case). The series is in remarkable accord with the preceding set. They indicate that the intensity of short wave length radiation may vary greatly. This, judged from the behavior of the cell, may take place quickly. Marked difference in apparent brightness of the sunlight and in the reading may take place in five or ten minutes when no clouds are visible.

3. *Percent at different levels.* The average percent of light at each level, is shown in table 5. In nearly all cases the cell while still

TABLE 5. *Showing percent of light at different depths in 1-10 meters.*

Depth	Average 16 readings		Average 8 largest readings		Selected maxima	
0 Dry	100	132	100	123	100	116
0 Wet	75.7	100	81.1	100	86.2	100
1	68.4	82.2	57.9	71.3	62.6	73.3
2	45.7	69.6	43.2	53.2	46.0	53.3
3	36.3	48.9	34.1	42.0	34.5	40.0
4	30.0	39.5	27.5	33.9	28.1	37.3
5	23.0	30.3	20.3	25.0	27.5	32.6
6	18.7	24.5	16.9	20.8	24.1	28.0
7	16.1	21.3	14.0	17.2	22.1	25.7
8	13.7	18.1	11.6	14.3	18.8	21.8
9	11.4	15.0	9.2	11.3	15.5	17.0
10	9.8	12.6	7.4	9.3	11.8	13.3

dry was first exposed to the sun and read, and then barely submerged ( $\frac{1}{2}$  cm below troughs of waves) and read. The percents given are computed from both the "dry" and the "wet" readings. The latter

is more important in studies of penetration into the deeper strata because it makes possible comparisons without regard to condition of surface. Table 6 shows the percent at depths of 10 meters or more.

TABLE 6. *Percent at different depths and average percent transmitted per meter to different depths.*

1	2	3	4†	5	6	7	8	
Depth in meters	Mean of all percents	Discordant readings rejected	Aug. 1, 1928, mean	Sun at zenith	128 volt readings	128 volt readings, Aug. 1, 1928%	Aug. 1, 1928%	Assumed Maximum values
0 Dry	132							
0 Wet	100		100		100			
5	30.3						81.4	84.5
10	12.6**							
	10.25*		10.24				81.4	85.34
	5.4°							
15	2.5°							
20				5.16			86.1	86.22
25		2.3	2.65	4.03	2.53	87.82	87.8	87.25
30				3.12				89.1
35		1.52	1.68	2.54	1.724	90.27	89.8	90.0
50		.90	1.01	1.59	1.204	92.28	91.97	92.0
75		.55	.577	.7516	.595	94.15	93.9	93.7
100		.276	.294	.3493	.275	94.92	94.87	94.5
120		.048	.108	.1909	.049	94.35	94.83	94.9
200				.01636				

#### 4. Percent transmitted by each meter and by the surface.

A. *Pure water.* Transmission is commonly expressed as a coefficient of absorption for one meter. "This is the reciprocal value of the thickness of the stratum of water which would reduce the intensity

of the transmitted light to the fraction  $\frac{1}{2.7183}$  of its value at entrance.

The number 2.7183 is the basis of the natural system of logarithms and the value of the fraction is approximately 0.37. This coefficient may be stated in terms of any desired unit of measure for the thickness of the stratum. In this case the meter is employed. An absorption coefficient of unity, therefore, means that a stratum of water whose thickness is unity (1.000 meter) absorbs so much light that the intensity of the transmitted light is equal to 0.37 of its original value. An absorption coefficient of .200 means that if the ray of light were passed through a

\* Average percent per meter.

\*\* Mean of all readings in table 12. The mean for Aug. 1, when good readings were made was 10.34%.

\*\*\* Mean of 16 readings

† Two readings at each level, July 27, water less clear than on August 1.

‡ The percentages in column 4 differ slightly from the same percents calculated from mean meter candles as they were calculated from the transmission coefficients.

§ Calculated from columns 4 and 6 corrected from .1 to 1 meters.

1.000

layer of water 5 meters thick—its intensity would be reduced to .200

0.37 of its original value. Similarly a coefficient of 1.250 would mean that 0.80 meters would reduce the intensity of transmitted light to 0.37 of its original value. For the purposes of this kind of investigation the results might as well be stated in terms of the percentage of the transmission of light by a meter of water as in those of the coefficient of absorption. The coefficient method is regularly used by physicists and is of advantage in certain types of computation." (Pietenpol, 1918).

Coefficients of transmission are advantageous. In table 7 the

TABLE 7. Showing transmission of light of different wave lengths by pure water (transmission coefficients)\*.

Wave length, mμ**	Per cent transmitted to depths meters noted									
	1M	5M	10M	20M	25M	30M	35M	50M	75M	100M
	(Exponents)	(1 <sup>st</sup> )	(5 <sup>th</sup> )	(10 <sup>th</sup> )	(5 <sup>th</sup> )	(10 <sup>th</sup> )	(5 <sup>th</sup> )	(25 <sup>th</sup> )	(25 <sup>th</sup> )	(25 <sup>th</sup> )
300.0 Sm	85.81	46.5	21.8	4.6	2.1	1.0	.47	.047	.001	.00003
415.0, E	96.59	84.0	70.6	49.9	42.0	35.2	29.0	17.6	7.6	3.1
420.0, E	97.74									
449.0, E	98.81	94.2	88.7	78.7	74.1	69.9	65.8	54.9	40.7	30.3
450.0, A	98.03									
468.0, E	98.81	94.2	88.7	78.7	74.1	69.9	65.8	54.9	40.7	30.3
470.0, P	96.67									
475.0, A	98.03	90.5	81.9	67.1	60.8	55.0	49.8	37.1	22.5	13.6
494.0, P	97.06									
506.0, A	98.03	90.5	81.9	67.1	60.8	55.0	49.8	37.1	22.5	13.6
510.0, A	97.54									
522.0, A	98.52	97.8	86.1	74.2	68.8	63.9	59.3	47.4	32.6	22.5
525.0, A	97.06									
537.0, P	99.50	97.5	95.1	90.5	88.2	86.0	83.9	77.8	68.6	60.5
539.0, A	97.93									
550.0, A	96.48	83.6	80.9	48.8	40.8	34.1	28.5	16.6	6.85	2.7
558.0, P	96.48									
562.0, A	97.06	86.1	74.2	55.1	47.4	40.8	35.3	22.5	10.68	5.06
575.0, A	98.03									
579.0, P	94.59	75.7	57.3	32.8	24.8	18.8	14.3	6.1	1.54	.38
587.0, A	95.06									
589.5, P	90.90	62.0	38.5	14.8	9.19	5.7	3.5	0.85	0.075	.0071
600.0, A	85.04									
600.5, P	84.87	44.0	18.3	3.76	1.6	.72	.32	.027	.0045	
610.2, A	82.68									
618.0, P	81.48	35.9	12.9	1.6	.59	.21	.077	.0035		
625.0, A	80.10	32.9	10.8	1.18	.39	.12	.0429	.0015		
636.0, P	79.96	32.6	10.6	1.14	.38	.12	.0396	.0013		
637.0, A	79.65									
640.0, A	77.61	28.0	7.92	.627	.18	.049	.014	.00013		
650.0, P	78.68									
662.0, A	75.64	24.7	6.11	.37	.09	.023	.0056	8.06x10 <sup>-4</sup>		
663.0, P	78.40									
675.0, A	72.10	19.48	3.79	.141	.028					
687.0, A	70.35	17.23	2.96	.088	.0151	.00045	2.31x10 <sup>-4</sup>			
700.0, A	67.83	6.4	.40	.00167	.000107	6.8x10 <sup>-4</sup>				
779.0 Sm	1.79x10 <sup>-10</sup>									

\* Calculated from coefficients by authors, or from the sources designated by letters: A, Aschkmass; P, Pietenpol; E, Ewan; Sm, Smithsonian physical tables. The data by Aschkmass and by Ewan are from Pietenpol.

\*\* Wave lengths correspond to colors as follows: 300, ultra violet; 415, violet; 430-506, blue; 510-525, green; 537-589.5, yellow; 600-640, orange; 650-700, red; 779, infra red.

percent transmitted by one meter (coefficient of transmission) and by several greater depths, are approximately shown according to several authors. It will be noted that the mean of the five determinations nearest the wave length to which the cell is most sensitive is 98.069% ( $.44\mu$  to  $.475\mu$ ); from  $.42\mu$  to  $.5060\mu$  is 97.896%; from  $.42\mu$  to  $.5790\mu$

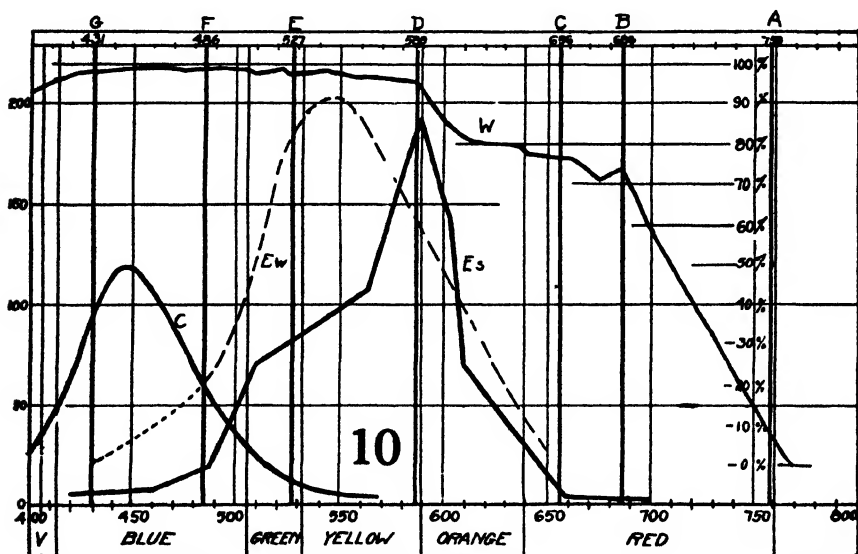


PLATE 28

Fig. 10. The curves indicate the following: (C), The color sensitivity of the K-H photo-electric cell (from Shinomiya); Coblenz has shown that the curve goes to about 10 of the scale at  $400\mu$ . (Ew). The sensitivity of the eye to 500 m. c. (from Smithsonian Tables); dotted extension at left for weaker light; ( $E_s$ ), The sensitivity to sunlight. (W), Percent for various wave lengths absorbed by 1 meter of pure water, from table 7.

is 97.80%. The cell should accordingly show approximately 98% transmission of average sunlight through pure water. The percent at  $n$  meters depth is the  $n$ th power of the percent transmitted by one meter.

*B. Puget Sound water.* Table 9 shows percent transmitted;—mean of 8 and 16 (all) readings shown in table 4, and 6 other sets to 10 meters, two sets from 10 to 20 meters. Other things being equal these figures should indicate the location of the maximum density of plankton and floating particles. The variation is, however, great. The

TABLE 8. Showing the estimated percent of light of different wave lengths transmitted through 100, 500, 1000 and 1800 meters of pure water, a continuation of table 7.†

Wave lengths in mu mu	Percent trans- mitted 1 meter	100 meters	500 meters	1000 meters	1800 meters
418.0	96.89	.....	$8.86 \times 10^{-8}$	$8.86 \times 10^{-14}$	$7.827 \times 10^{-28}$
537.0	99.56	.....	8.18 ..	.668 ..	.012
589.8	90.90	.....	$1.91 \times 10^{-19}$	$3.66 \times 10^{-40}$	$8.61 \times 10^{-73}$
600.5	84.87	$7.5 \times 10^{-6}$			
618.0	84.68	$1.27 \times 10^{-7}$			
685.0	80.10	$8.30 \times 10^{-8}$	$8.86 \times 10^{-47}$	$4.89 \times 10^{-98}$	
636.0	79.96	$1.93 \times 10^{-8}$			
640.0	77.61	$9.81 \times 10^{-10}$			
648.0	78.64	$7.53 \times 10^{-11}$			
687.0	70.38	$8.22 \times 10^{-14}$	$4.88 \times 10^{-75}$		

TABLE 9. Showing the observed percent transmitted by each meter, each 5 meters, each 10 meters and each 20 meters.§

Column Number 1	2	3	4	5	6	7	8	9	10	11	12	13
Date	-	-	-	-	7/27	7/18	7/19	7/19	7/28	7/19	-	-
Hour	-	-	-	-	11 AM	1 PM	2 PM	3 PM	1 PM	4 PM	-	-
	Mean 8 Readings		Mean all 19 readings									
Surface	1.13	1.00	1.11	1.00	80.0	69.0	84.0	*	85.0	*	Mean	
1st Meter	85.6	87.0	82.2	84.0	73.0	75.08	81.2	76.2	81.8	85.5	77.6	MAX
2d "	73.3	75.8	73.3	80.3	84.2	75.5	73.8	81.2	71.0	79.1	77.4	84.2
3d "	79.3	81.2	79.3	81.2	86.3	85.4	82.1	80.6	77.8	80.1	85.2	90.6
4th "	79.3	81.2	82.4	84.0	94.0	78.2	77.8	80.5	74.8	80.7	83.4	94.0
5th "	76.8	79.0	76.8	78.9	89.2	88.5	78.8	79.3	71.5	82.3	78.2	89.2
8th "	81.4	85.0	80.1	82.0	89	73.8	78.8	80.4	78.2	80.9	80.4	89.0
7th "	84.2	87.8	84.2	87.8	89	69.0	78.9	79.0	75.1	83.7	78.9	89.0
9th "	86.6	87.1	85.2	86.5	84.2	78.2	83.8	82.5	79.3	85.2	81.5	84.2
10th "	83.3	84.9	80.7	87.0	82.5	76.0	80.2	73.8	73.0	78.0	77.2	12.8
Mean	83.9	88.4	83.8	85.2	87	80.8	84.7	78	80.8	81.2	83.5	89.5
1st 5 Meters	78.8	80.5	78.8	81.9	81.1	76.3	78.8	83.6	77.1	82.3	80	89.9
2d 5 "	84.1	85.4	84.2	85.6	84.7	75.0	81.3	78.5	71.5	84.5	80.1	87.3
1st 10 "	81.5	83.1	81.5	83.7	83.9	75.6	77.9	81.0	77.3	81.8	80.1	84.5

Depth in meters	Selenium photometer			Maximum col. 9-11		Maximum col. 11-12		7/27	1.00
	Hammel's Readings	% of sun at Diff. depths	% Trans- mission	1st 5 meters	83.6	11th meter	83.1		
0 fms	Reading			2d 5 "	86.7	12th "	81.7		
1	135	81.9	81.9	1st 10 "	83.9	13th "	87.9		
2	108	40.4	77.7	Means		14th "	87.5		
3	89	36.5	90.8	5th 5 meters	86.0	15th "	78.4		
4	89	34.3	93.7	6th 5 "	86.9	16th "		86.8	84.3
5	88	32.7	90.5			17th "		84.4	82.5
6	82	31.5	96.5	not determined		18th "		84.3	85.5
7	80	30.8	97.6	† Figures below are reduced to 1.00 meter		19th "		85.1	86.5
8	78	30.0	97.6			20th "		85.1	87.2
9	77.5	29.8	99.4			Means		86.7	88.0
10	77	29.6	99.4			2d 5 meters		86.0	88.2
						4th 5 "		86.9	87.1
						1st 20 "		....	83.5

† Giehl reports only violet light at 1500 meters where he got effects on the photographic plates used. The data of other workers suggest some narrow transmission bands in the spectrum, for example 537 mu mu, as shown in this table.

§ The means are arithmetical, but differ from geometrical means as a rule only in the first or second decimal place. While much of the variation from meter to meter is not significant, it was obvious that in some cases the low transmission was due to the presence of much plankton in certain meters.

\*\* Column 6-11 inclusive



greatest number of low readings and the low point in the averages appears to be in the fifth and sixth meters which is the location of the greatest amount of plankton. In the July 27 reading the 53% transmitted by the first meter was correlated with a phyto-plankton at the surface which made the water appear green. A great many factors enter into the variation from meter to meter as the apparatus was lowered. The most important of these are

1. Changes in small waves and whirlpools at surface.
2. Changes in the atmosphere.
3. Changes in quantity of suspended matter due to tidal currents.

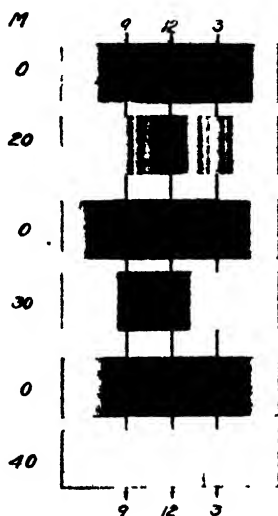
A cell on deck and a cell submerged read at the time of each deep reading would obviate the surface and atmospheric differences and would probably make possible a determination of the greatest quantity of plankton.

TABLE 10. *Showing the effect of currents on light penetration during 7 minutes, east of Brown Island at Friday Harbor; the mean of columns a and b is 63.8.*

July 19							Other dates	
Surface	Sun time, Hr. Min	Zenith distance		m c light units		%	Angle	b Surface transmission
		Air	Water	Depth				
Covered-----	3:10	47°	.....	0	0	.....	27°0	82.5
Dry-----	3 12	47°	.....	0	483	100	27°5	68.5
Tide ripples-----	3:13	47°	33°16'	0 Wat	306	63.0	29°	98.0
" "-----	3:14	47°	33°16'	" "	388	67.3	32°	73
" "-----	3:15	47°	33°16'	" "	306	63.5	32°	80
More tide ripples-----	3:16	47°	33°16'	" "	298	60.6	37°	89
Froth-----	3:17	47°	33°16'	" "	126	26.0	37°	86
Strong tide rips-----	3:18	48°	33°52'	" "	223	46.1	37°	33
" " "-----	3:19	48°	33°52'	" "	233	46.7	70°	42.4

C. *Importance of surface conditions.* Table 10 shows the great rapidity with which changes in surface may be encountered in a boat drifting with the tide. It shows also the marked effect of surface conditions. This is probably the most important knowledge gained in the investigation. It will be noted that the movement of the water due largely to tidal currents enormously reduces the amount of light penetrating the water. This may serve to explain irregularities in depths

at which plants and animals live in some parts of the sea as compared with other parts where there appears to be no explanation. It also probably explains the peculiar results obtained by Regnard with his clock work photometer, which on unusually fair days showed marked differences between the instrument on deck and the instrument lowered in the water as shown in his figure (see Fig. 11).



11  
PLATE 29

Fig. 11. Regnard's results of exposing the instrument shown in Fig. 1 at 20, 30 and 40 meters with a similar instrument on deck. The effect of changes in surface conditions is probably indicated by the lack of accord in the light effected bands of photographic paper.

The large amount of light shut out by the surface and the few centimeters to which it was necessary to submerge the cell on account of surface condition, has seemed to some quite incredible. The variation within 7 minutes shown in table 10 constitutes an adequate explanation. It should be noted also that the surface transmission changed from 67.3% to 26.0% in three minutes (3:14 to 3:17 p.m.) with increasing surface disturbance. When the tide is running through narrow channels the surface is characterized by innumerable whirlpools. These are crossed by wave motion making a very complicated surface. The surface of rivers is similar but that of lakes is probably less complicated.

These variations indicate the great importance of continuous records of light penetration into water as a means of determining the average for different kinds of situations, and under different weather conditions. In computing the heat received, for example, it is probably impossible to compute accurately the amount of heat penetrating water per year because the surface effect is not well enough known to be taken into account.

It is apparent from the study of the table 8, 9, and 10 that the surface may transmit from 92 to 26% of the light under conditions such as we measured. The results of Regnard and the often quoted statement that  $\frac{1}{2}$  the light is shut out by the first meter is shown to be not true. The average amount transmitted by the surface is 75% and by the first meter 80% (blue), making the amount transmitted to 1 meter  $.75 \times 80\%$ , or 60%. Choosing the two lowest readings of 53% and 26%, the percent at the depth of 1 meter would be 13.78%; choosing the largest reading, 92% and 88%, the percent at one meter would be 80%. The mean of all readings will be seen to be 63.5% transmitted by the surface, which is perhaps a fair average for summer, but too high for winter.

TABLE 11. Showing the percent of light transmitted per meter by 5-meter intervals. The transmission by pure sea water to the wave lengths measured by photoelectric cell is taken to be 98 percent. The effect of foreign matter is indicated.

5-Meter intervals	Pure water	Mean of all readings	Effect of foreign matter	Mean of 5 readings	August 1, 1920	July 17, 1920	Maximum observed
1	2	3	4	5	6	7	8
1st	98	81.9	18.1	80.0	81.4	81.1	89.6
2nd	"	86.6	12.4	80.3	81.4	86.7	86.7
3rd	"	88.0	10		88.0	....	88.0
4th	"	86.8	11.8	Larger readings rejected	88.0	86.8	86.8
5th	"	86.0	7.8		88.0		
6th	"	86.0	8.1	86.8	86.9		
7th	"	86.0	8.1	86.8	86.9		
8-10th	"	86.0	1.8	86.8			
11-15th	"	87	1.	86.8			
16-20th	"	87.88	.78	87.6			
21-24th	"	86.8	8.8	88.8			
25-30th	"	86.8	1.88	86.1			

TABLE 12. Showing percent of light which enters the water and reaches 10 meters at different hours.  
Mean of all readings is 10.25 percent.

	A. M.					M.					P. M.				
	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8
Nearest hour -----															
Aug. 1 and 2; time -----	4:53	5:53	7:50	8:30	9:40	11:15	12:15	1:15	1:51	2:00	4:25	5:00	6:00	7:00	7:45
Percent at 10 meters -----	18.7	21.3	7.50	10.5	7.7	9.5	6.9	13.9	7.2	10.5	11.6	10	13.5	26.6*	0
Angle of rays in degrees -----	89.6	80	71	61	55	41	31.5	22.5	35.5	30	43	59	70	81	90†
Angle of rays in water -----	46.6	47.2	46.1	41	36.2	29.1	22.8	16.7	24.8	26	26.7	40.0	44.6	47.8	48.8
Secant -----	1.80	1.47	1.41	1.32	1.24	1.14	1.06	1.04	1.10	1.10	1.20	1.40	1.48	1.80	1.88
Dates -----					7/27	7/27	7/27	7/28	7/28	7/28	7/28	7/28	7/28	7/28	7/28
Hours -----					10:50	11:52	12:54	1:55	2:10	3:00	4:36	5:7	6:7	8.1	9.1
Percent at 10 meters -----					18	14.9	6.9	5.8	8.2	7.1					
Angle of rays -----					25	21	27	34	39	46					
Angle of rays in water -----					24.1	22.7	20	24.8	26.2	21.9					
Secant -----					1.09	1.06	1.06	1.10	1.13	1.16					

\* Light too weak to read accurately.

5. *Average transmission to various depths, etc.* Tables 11 and 13 include estimates of average transmission per meter to each of several depths, both theoretical and actual values are shown. The theoretical values are based on the average, and on the assumption that floating and dissolved foreign matter must at all times shut out 1% of the light. Table 11 shows the average transmission per meter for each 5 meters of group of 5 meters. From the facts shown in table 3, and from the constant *presence* of floating foreign matter in the water, readings much above 97% are open to question. Indeed the number of readings below 25 meters was too small for certainty of their accuracy, but the visibility of the Disc of Secchi at 60 meters in the Pacific suggests readings of some such magnitude. The mean transmission of short wave lengths to which the eye is most sensitive is only 92-93% in pure water.

6. *Percent of light at 10 meters at different hours.* A number of readings were taken, distributed throughout the day of August 1 and 2. The distance which the light would have to traverse the water is given. Comparisons were made on the basis of the actual distance penetrated by the direct rays of the sun. The sky at sunset probably afforded 355 m.c. The sky directly overhead probably gave readings of zenith value while the entire blue dome supplied a cone of light to the cell. Thus the ratios should be largest when the sun was not shining on the water, due to its being below the actual horizon; or when the sun was so low as to cause a complete reflection of its direct rays.

7. *Discussion of methods of treating results.* The data collected indicate that the chief difficulties in the study of light penetration in sea water are: (A) Variability of surface; (B) Varying amounts and location of foreign matter. To solve the former problem continuous, simultaneous records of intensity above and immediately below the surface are necessary and are probably practicable. Such records will show the amount of light entering the water under all conditions. The best substitute for this is frequent readings. Unfortunately we did not succeed in making a large series of these readings as our attention was focused chiefly on penetration through the water. In this type of study where a single cell must be used, the most accurate results may be obtained by computing the per cent transmitted by each meter or other intervals used. This compares readings taken very close together in point of time, thus minimizing changes in atmosphere, water surface, floating particles and organisms. Table 13 was prepared as

TABLE 13. Showing the effect of foreign matter in sea water, percent transmitted per meter at different depths, percent transmitted by foreign matter considered separate from the water, and percent of different colors at different depths, August 1, 1920, 9 A. M. to 3 P. M.\*

1	2	3	4	5	6	7	8	9	10	11
Depth in meters	Foreign matter effect	Readings % Trans.	Foreign matter %	Blue 98.0 97.7	Green 97.7 97.4	Yellow 97.0 96.6	85.0 83.2	Orange 89.0 77.7	Red 78.0 75.5	Red 87.0 83.0
1	18.7	79.0	80.86	79.0	78.7	78.1	67.3	62.0	61.0	42.8
2	18.7	79.0	80.86	62.4	61.9	60.9	.....	39.4	37.2	18.3
3	18.7	79.0	80.86	49.2	48.7	47.5	.....	24.7	22.7	7.86
4	18.7	79.0	80.86	38.8	38.3	36.0	.....	15.5	13.8	3.36
5	18.7	79.0	80.86	30.6	30.1	28.9	13.7	9.7	9.4	1.43
6	17.7	80.0	81.90	24.4	23.9	22.8	9.33	6.19	6.09	.634
8	16.7	82.0	82.90	15.9	15.5	14.6	4.48	2.549	2.38	.120
10	14.3	83.5	85.46	11.0	10.7	9.9	1.132	1.132	.99	.0543
12	10.7	87.0	89.4	8.9	8.0	7.3	.....	.510	.421	.0131
15	9.7	88.0	90.07	6.0	5.3	4.8	.....	.153	.132	.0013
20	8.7	89.0	91.09	3.3	2.9	2.53	.....	.02849	.0188	.00028
25	6.7	91.0	93.14	2.0	1.78	1.49	.....	.00564	.0032	.....
30	3.2	94.5	96.72	1.6	1.32	1.06	.....	.00135	.00067	.....
35	3.2	94.5	96.72	1.13	.97	.754	.....	.000323	.....	.....
40	3.2	95.5	97.74	.89	.75	.565	.....	.....	.....	.....
45	2.2	95.5	97.74	.70	.58	.423	.....	.....	.....	.....
50	2.2	95.5	97.74	.55	.45	.317	.....	.....	.....	.....
75	2.2	95.5	97.74	.17	.13	.0752	.....	.....	.....	.....
100	2.2	95.5	97.74	.053	.037	.0178	.....	.....	.....	.....
120	2.2	95.5	97.74	.021	.0137	.....	.....	.....	.....	.....
125	2.2	95.5	97.74	.016	.0108	.00421	.....	.....	.....	.....
150	2.2	95.5	97.74	.006	.0031	.0010	.....	.....	.....	.....
200	2.2	95.5	97.74	.0006	.00026	.00009	.....	.....	.....	.....

a working table. It was derived by a study of tables 9 and 11. The calculated percents transmitted in table 11 are derived from various means shown in table 9, and as a ratio between percents shown in table 6.

The general procedure which illustrates the general plan of work in the paper, was as follows: The ratio (transmission or percent transmitted,  $T$ ) for any layer of water when readings were taken at its top

Bottom reading

and bottom with the sun directly overhead is  $\frac{\text{Bottom reading}}{\text{Top reading}} = T$  for  $n$

Top reading

meters depth. The light usually passes obliquely thru the water so that the distance traveled is greater than the depth. This distance was calculated from the sun's zenith distance and the refractive index of water. The average distance per meter for all readings was 1.11 meters per me-

\* The transmission coefficient for the rays measured by the photo-electric cell for pure water is 98%. The mean oblique distance per meter of depth for the day and hour is 1.13 meters. .981%, or 97.7%, is the percent transmitted per meter of depth by pure water for the rays measured by the cell. The percent transmitted per meter shown in column 3 is derived from tables 6, 9 and 11 by careful inspection. The foreign matter effect is derived by subtracting the figures in column 3 from 97.7, and the percent transmitted by foreign matter is derived by dividing the figures in column 3 by 97.7. The percents transmitted by the different colors are derived from table 7, each being a reading about the center of each color. The highest red reading was selected on account of the possible staining of sea water (see p. ....). Both the first and the 1.13 powers are shown. The percents at different depths are calculated from the figures in column 4 and the 1.13 power of the transmission of the color in question except the blue. The surface transmits 75 percent. The cell barely submerged is called 100 percent in columns 5-10.

ter of depth. In this case  $n=1.11$  and  $T$  for one meter is  $^{1.11}\sqrt{T}$ . Since the coefficient of the transmission for the oblique distance was usually about .85; the transmission coefficient for 1 meter was a larger fraction (see last two columns of table 2). Also in case we know the transmission per meter for any kind of water the amount reaching a depth of 1 meter under the conditions described is  $T^{1.11}$ , or  $T$  raised to the 1.11 power.

In table 13 the data have been treated in such a manner as to show the order of magnitude of relative intensity of different colored lights at different depths. Table 11 shows percent transmitted per meter. The figures approach too near .98 (pure water) to be satisfactory for averages 35 to 100 meters (column 3). With discordantly large readings rejected, averages from 25 to 50 meters seem reasonable. These deep water readings were taken with conditions of air and water improving. It was impossible for us to change our "set up" to read shallower depths for comparison after the beginning and it is not strange that such a difficulty should arise in so small a series nor is it impossible that water at these depths is quite clear; 96 was selected for depths below 40 meters. Other figures were selected by inspection from table 11. The transmission of pure water for the wave lengths measured by the cell is taken to be .98. The mean path of the rays taken at hour intervals from 9 a.m. to 3 p.m. on Aug. 1 was 1.13 m. per m.  $(.98)^{1.13}$  is .977. The transmission coefficients in column 3 are approximated to be 1.13 power of the values selected. 97.7 less the values in column 3 gives the supposed effect of floating matter which Pietsenpol found did not have a selective effect in lake water. The values in column 5 are the product, meter by meter, of transmissions given in column 3. The transmission of green, yellow, orange, and red light is taken from table 7. Each value thus derived is raised to 1.13 power. From this the transmission coefficient of foreign matter and coloring matter in the water, considered separately from the water (considered as pure water), may be derived. For example .79, or 79%, is the product of 97.7% and an unknown which represents the foreign matter in the water. Thus by dividing .79 by .977 we get .8086, the coefficient for foreign matter. Thus in column 3, table 13, the foreign matter coefficient is given, having been derived by dividing the coefficient actually found by .977. This is a correct procedure for the known values and it is obvious that the penetration for any wave length shown in table 7 can be derived from known foreign matter coefficients in column 3 and data given in table 7, provided that the foreign matter

is not selective. Pietenpol has shown that the solids in the Wisconsin lakes are nonselective as to wave length transmission. However he found that the waters were stained with extractions which were various in effect but usually screened out least of the yellow. We know nothing of the conditions of Puget Sound water in this respect, but such staining would presumably be of relatively little importance in the sea. It is however necessary to assume that a slight staining occurs in spring as a result of humus accumulations in the mountains in winter (Van Winkle, 1914). The streams tributary to Puget Sound, in so far as published reports are available, are referred to as clear, but some other streams such as the Chehalis which flows directly into the Pacific, show a marked staining in spring. Pietenpol has shown that such stains disappear after a time. However we have chosen the highest determined transmission coefficient for red light to use in table 13 to avoid under estimating those wave lengths which disappear most rapidly. The transmission coefficients of green, yellow and orange used in table 13 are chosen as representative or about the center of the color.

To secure the coefficient of transmission for any color, the transmission coefficient for that wave length through pure water is first reduced to the required oblique distance coefficient, which in table 13 is 1.13. The resulting value is multiplied by the foreign matter coefficient of transmission which has been calculated from the measurements of blue with the photoelectric cell.

Figure 12 was constructed to show graphically the distribution of relative energy and colored light at different depths. The curves are roughly drawn from the values given in table 13. The energy curves indicate that the energy available for photosynthesis lies chiefly in the blue and green. Such conceptions are essential to an understanding of the behavior of plants and animals in relation to colored light, and to successful experimentation on growth and photosynthesis. In view of the unsatisfactory character of screens such calculations are of importance.

8. *Screens.* The muslin used by Gail was examined in the department of physics of the University of Illinois and found to be non-selective in effect. Commercial red, blue and green glasses available at the station were also examined roughly. The transmission coefficients of these in percent are as follows:

Glass	Red	Orange	Yellow	Green	Blue	Violet
Blue	4.17	4.4	6.6	23.3	40.0	not determined
Green	0	8.8	13.3	50.0	9.17	0
Red	50	0	0	0	0	0



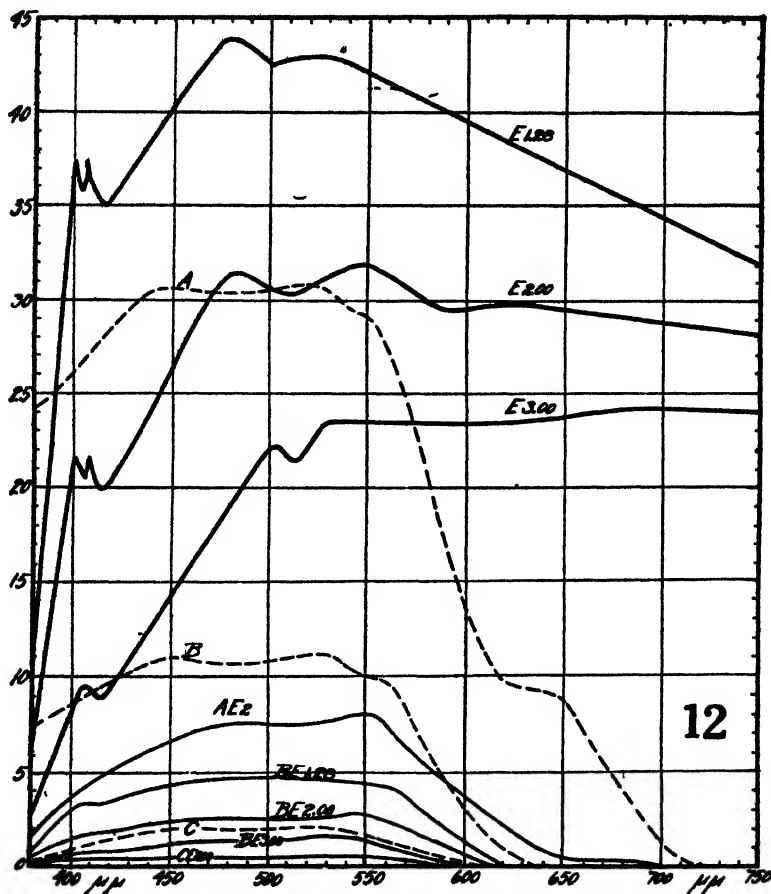


PLATE 30

Fig. 12. Curves showing an estimate of the percent of light at different depths, the sun's energy through different atmospheric paths, and the energy curves for different depths and air masses. The curves are as follows: (A), Percent of light entering the surface transmitted to 5 meters by Puget Sound water under conditions described for table 13. (B), The same for 10 meters; (C), The same for 25 meters. Curve E1.28 shows the sun's energy, drawn to an arbitrary scale, after passing through 1.28 air masses, which is the mean for midsummer (table 13), 8 a. m. to 3 p. m., at Friday Harbor; curve E2.00 is the energy through two air masses, which is the mean for the day from about 7 a. m. to about 5 p. m. in summer; curve E3 is the energy through three air masses, which is about 7 a. m. and 5 p. m. in midsummer (curves from Abbot and Fowle, 1908; data for Washington, D. C.). The subaquatic energy curves AE2 etc., are products of the corresponding percentage and relative energy curves. Two and three air mass percent curves from which E2 and E3 curves are drawn for different depths

are not shown. The subaquatic secant distances corresponding to the 1.28, 2.00 and 3.00 air masses are, respectively, 1.13, 1.31 and 1.40. The curves show that the energy for photosynthesis lies chiefly between  $430\mu\mu$  and  $580\mu\mu$ , the center of sensitivity for the K-H photo-electric cell falling at  $445\mu\mu$ , stands at an average point in the energy curve. The subaquatic energy is highest at about  $470\mu\mu$  near noon and for the midday period during the time of longest days.

The products of the coefficients shown give a result out of accord with the results of passing light through water. Of the colored glasses in common use, Bausch and Lomb Fieuzal A and Smoke A in combination as shown in "Optical Glass" by Bausch and Lomb approach very closely to one meter of Puget Sound water as indicated in table 13.

The work of Grein (1913) in which photographic methods were used, gave results which do not seem in accord with other observations either on pure or natural waters.

There is no doubt that photo-electric cells made from the various alkali metals already tried, with the use of selected optical glass for bulbs, will make possible a thoroughly scientific enquiry into the selective absorption of sea water. The cells used were tested to pressures equal to 400 meters depth, and high sensitivity galvanometers on which small effects can be read are in use on cable ships. Such galvanometers are made by Leeds and Northrup. A continuous record of light intensity throughout the year at such depth as is necessitated by waves is merely a question of a little special glass blowing on the cell used and some difficulty in constructing a float to carry it. The recording device has already been made (for the sunlight cell designed by Mr. Theodore W. Case of the Case Research Laboratory, Rochester, N.Y.) by the Leeds and Northrup Co.

## VI. RELATION TO PLANT DISTRIBUTION

It is a well known fact that most of the brown algae grow near the shore or in shallow water and that most of the red algae grow in deeper water. So far as the writers have been able to ascertain, no study has been made of the exact depths at which these algae grow; nor has any attempt been made to determine any measure of the quantities of these algae at the different depths at which they grow.

This does not mean that the marine algae are always found at certain depths. The roughness of the water and the kind of bottom, if rock, gravel or mud, are some of the controlling factors. The algae were found in quantities indicated in the following table in localities where the Petersen hard bottom-sampler was used (see Kirsop, 1922, Fig. 6 and stations).

TABLE 14. Showing the number of individuals of the brown algae per square meter of bottom and the depth at which they occur, based on 10 samples.

Depth in meters _____	1 - 5	5 - 10	10 - 15	15 - 20	20 - 25	25 - 30	30 - 35
<i>Oostaria costata</i> _____	4	0	5	2			
<i>Laminaria</i> sp. _____	3	5	6	1			
<i>Alaria</i> sp. _____	5	0	2.5	2			
<i>Agarum fimbriatum</i> _____		5	5	5			
<i>Cymathere triplicata</i> _____		1	5	1			
<i>Desmarestia aculeata</i> _____	1	0	5				
<i>Desmarestia ligulata</i> _____		2.5	22	10.5	7.1	2.0	

The table shows the depth at which some of the brown and red algae grow and the number of individual plants found at the various depths, based on 10 samples. As the area of the bottom sampler is one-tenth of a square meter, tables 14 and 15 show also the number of algae occurring per square meter.

Tables 14 and 15 show that the majority of the brown algae grow between 5 and 15 meters in depth. There are at least two brown algae

TABLE 15. Showing the number of individuals of red algae per square meter of bottom, and the depth at which they occur, based on 10 samples.

Depth in meters _____	1 - 5	5 - 10	10 - 15	15 - 20	20 - 25	25 - 30	30 - 35
<i>Bonnemaia hamifera</i> _____					4		
<i>Dasyopsis plumosa</i> _____		1	15	15	10	2	
<i>Callophyllis</i> sp. _____		14	15.7	7.5	2.5		
<i>Nitophyllum latissimum</i> _____				5	15		
<i>Nitophyllum ruprechtianum</i> _____			3	5	7		
<i>Agardhiella tenera</i> _____		17	6	11	9	5	1
<i>Anatheca furcata</i> _____			4	4	2.5		
<i>Rhodymenia pertusa</i> _____		1	10	5	5		
<i>Pterosiphonia</i> sp. _____				5	1.5		
<i>Callymenia phyllophora</i> _____				5	15	5	
<i>Butthora fruticulosa</i> _____			4	5	4		
<i>Polysiphonia</i> sp. _____		5	5	5			
<i>Gigartina radula</i> _____				2.7	5		
<i>Iridaea laminarioides</i> _____		1	5	5	15		
<i>Odonthalia semicostata</i> _____			5	15.4	5		
<i>Haloacccion glandiforme</i> _____			4	25	20	4	
<i>Plocamium coccineum</i> _____			5	5			
<i>Constantinea subulifera</i> _____				1	5		
<i>Laurencia pinnatifida</i> _____		1		2			

that grow at depths that do not conform to these figures. The table shows *Desmarestia ligulata* growing most abundantly between 10 and

25 meters. *Cymathere triplicata* and *Agarum fimbriatum* also grow at somewhat greater depths than the majority of the browns. The cause of these exceptions is yet to be determined but is probably connected with photosynthesis. It will be seen by comparison with table 13 that the brown algae cease to be present in any quantity where shorter wave lengths are reduced to about .02 of full sunlight. They are most abundant where the shorter wave lengths are from 30 to 67, and the red from 9.4% to .132% of full sunlight. *Nereocystis* grows in water at 3-20 meters, but was not secured with the bottom sampler.

The majority of the red algae grow most abundantly between 10 and 25 meters in depth. Here it should also be stated that there are exceptions. *Prionitis lyallii* is only found in tide pools and in very shallow water as at Argyle. *Halosaccion glandiforme* has a low tide form which is much larger than the form growing at a depth of 15 to 25 meters. The form growing at low tide has a greenish red color. *Agardhiella tenera* grows abundantly at 5 to 10 meters and also at 15 to 25 meters. The shallow water form is brownish in color and the deep water form has a deep red color. The causes of these exceptions need further investigation.

The depth at which the algae grow is determined to a considerable extent by the condition of the surface of the water. In water that is continuously more or less rough, as at Point Caution, either through the action of the waves or of tide rips, the algal zone has its lower limit nearer the surface than in waters that are usually calm. The algal zone under these conditions is greatly diminished or even entirely disappears.

The red algae begin where the red and orange light is reduced to about 1%, and extend to where the red light is approximately .0032. They are most abundant where the shorter wave lengths are approximately 2.9. The depth at which the red algae grow, when compared with these wave lengths, probably gives a clue to the reason for the red color of the algae growing in the deeper water.

An examination of Fig. 12 in which BE<sup>2</sup> shows the energy available at the upper limit of the red algal zone, and CE<sup>2</sup> at the lower limit, indicates that the energy for photo-synthesis must be drawn from wave lengths 420 $\mu\mu$  to 610 $\mu\mu$ , mid blue to orange and mostly from the blue, green and yellow. In the same figure, line AE<sup>2</sup> shows the distribution of energy just below the upper limit of the brown algal zone. The curve for the lower limit is not shown, but lies very close to % of light

curve C. It will be seen that the energy for photo-synthesis may be drawn from wave lengths  $400\mu$  to  $700\mu$ , blue through red but largely from blue, green, yellow and orange. Further investigation in the depth where the maximum and minimum amount of photosynthesis takes place in both the red and brown algae is now in progress.

A study was also made of the distribution of diatoms in plankton material. Three different nets having the shape of a cone were used for this purpose. The basal portions of the nets were sewed firmly to wire rings. All nets were about 90 cm long and about 30 cm in diameter. The nets were fastened to a cable which was marked in 10-meter lengths, so that the depths could be easily recorded as previously stated. The cable was lowered and raised by the machinery of the steamboat. A rock trawl was fastened to the end of the cable, which aided in keeping the cable in a more nearly perpendicular position. The angle which the cable made on being lowered into the water due to the action of the tide was estimated. This was necessary in determining the actual depths at which the tow was obtained. The tow was collected in jars and allowed to settle. The upper half of the water was discarded.

Water containing the diatoms was secured by the use of a medicine dropper. This was examined under a compound microscope to determine the number at each depth. The greatest number of diatoms was found in the first three meters of water. The number of diatoms in the first meter varies with the conditions of the water. There is a reduction in the number of diatoms in tide rips at least in this first meter. Below three meters, the number of diatoms gradually diminishes. Below eight meters, few or no diatoms were found. Gail (1918) found that in growing the sporelings of *Fucus* on shells suspended on cords in the Sound that no diatoms grew on the shells below 6 meters.

By a comparison with table 13, it will be seen that diatoms apparently extend only to depths at which the short wave lengths are about 15% and the longer wave lengths about 2% of full sunlight.

An examination of Fig 12 line AE<sub>2</sub> for 5 meters, which is the center of abundance for diatoms, shows that the energy for photosynthesis for the diatoms may be drawn from wave lengths  $400\mu$  to  $710\mu$ , blue through mid-red. The diatoms use all colors; the colors most available are blue, green, yellow and orange, but considerable amounts of the red are also available.

## VII. SUMMARY OF CONCLUSIONS

1. In calm clear weather between 10 A. M. and 2 P. M. about 25% of the light is shut out by the surface of the water. In rough weather this may be increased to 60 or 70% or more.

2. Regnard's statement that the first meter of water shuts out half the light is incorrect, as the surface shuts out about 25% and the first meter about 20%, so that the great mass of organisms living in one meter of water or less receive more light than has been supposed.

3. From 8 to 10% of the shorter wave lengths entering the surface reaches a depth of 10 meters. Regnard's figures are too large, as they indicate a transmission in the lower strata, greater than that for pure water.

4. The transmission determined for different meters indicates that floating materials differ from time to time, sometimes being concentrated at the surface and at other times being at 5 meters or other level.

5. If the lower limit of the distribution of organisms is determined by light it may be expected that regions with surface roughened by tide or waves will have a shallower lower limit than regions with calm waters. A maximum depth limit which will double the minimum is to be expected.

6. The amount of light of different wave lengths at different depths may be calculated from measurements with the Potassium-Hydrogen p.e. cell, and the amount and source of energy estimated. Between 5 and 25 meters the maximum energy for photosynthesis lies in the blue during midday.

7. The brown algal zone is with a few exceptions between 5 and 20 meters in depth. The majority are at about 10 meters in depth where the shorter waves are about 10% and the red about .99% of full sunlight.

8. The red algal zone with a few exceptions is between 10 and 30 meters in depth. Most red algae are found between 15 and 25 meters where the shorter wave lengths are between 10 and 2% and the red between .99 and .0032% of full sunlight.

9. The depth of the algal zones is considerably less, or the zone may be entirely wanting, if the surface of the water is roughened by tides or waves.

## VIII. ACKNOWLEDGMENTS AND BIBLIOGRAPHY

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# **Photosynthesis In Some of the Red and Brown Algae as Related to Depth and Light**

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## **INTRODUCTION**

During June and July of the summer of 1920, while at the Puget Sound Biological Station, Shelford and Gail (1922) made a study of light penetration in the waters of the Sound. At the same time, a study was also made by the writer of the quantities of red and brown algae growing at different depths. It was found that these algae grow in rather definite zones in regard to depth. It was, however, determined by measurement that the same species grow at considerably shallower depths in rough than in quiet waters. The quantities of the species are greatly reduced or disappear entirely if the waters are rough and also deep. The rough and deep water accounts at least in part for the scarcity of algae growing in the deeper and rougher water about Point Caution.

Light measurements made by Shelford and Gail (1922) with the Kunz photoelectric cell showed definitely in calm, clear weather that 25 percent of the light is shut out by the surface of the water between 10:00 a.m. and 2:00 p.m. In rough water, this may be increased to 50 to 70 percent or more. It was also found that in clear, calm weather, only 8 to 10 percent of the blue and green light entering the surface reaches a depth of 10 meters. These facts and the scarcity of algae growing in deep or rough water pointed to the possibility that there might be insufficient light under these conditions for the plants to carry on photosynthesis in sufficient quantity to sustain their life.

So far as the writer has been able to ascertain no quantitative work has been done on the photosynthesis in the marine algae. The writer, therefore, set out to make a quantitative study of the photosynthesis taking place in some of the red and brown algae at different depths and under different weather conditions in the Sound, during August of the summer of 1920 and throughout the entire summer of 1921. The object was to determine the following points: (1) Are there depths at which a maximum amount of photosynthesis takes place for the red and brown algae? (2) Is there a lesser amount of photosynthesis taking

place in rough water than in calm water at the same depth, due to a considerable portion of the light being reflected at the surface? (3) What effect has cloudy weather on photosynthesis? (4) Is the distribution of the red and brown algae into rather definite zones related to photosynthesis?

#### METHOD

The amount of photosynthesis occurring in the algae, under investigation, is considered proportional to the amount of oxygen produced. This is a fact which has long been recognized. The amount of oxygen produced was determined by the standard Winkler method.

Glass stoppered bottles holding about 250 cc were calibrated and are termed oxygen bottles.

The water used in filling the oxygen bottles for the first few experiments was obtained in the following manner: An air pump was connected in series with a bottle having a capacity of 750 cc, and this by a connecting tube with the oxygen bottle. A delivery tube which reached nearly to the base of the oxygen bottle extended three meters vertically into the water of the Sound. A partial vacuum was created by pumping and the sea water entered through the delivery tube. Pumping was continued until the 750 cc bottle was filled. This made it certain that the water in the oxygen bottle had not been exposed to the oxygen of the atmosphere and that the water had come from the desired depth. It was thought that equal volumes of water secured by this method would have the same oxygen content. Quantitative tests for oxygen showed that this was not always the case, and the method was modified. A carboy was held in the water of the Sound about 3 inches below the surface and filled with sea water. The delivery tube was now inserted through the mouth of the carboy and allowed to extend nearly to its base. With this one change, the same method was now used as before. The oxygen content of equal volumes of water was now found to be practically identical when the carboy was used as a reservoir since the effect of under currents of water was eliminated.

Five trays were now constructed of lumber for the purpose of holding oxygen bottles. The trays were  $6\frac{1}{2}$  by 8 inches and had a depth of  $\frac{1}{2}$  inch. Two division slats were nailed in each tray in such positions that three oxygen bottles could be laid horizontally side by side, without mutual contact. The depth of the tray and the height of the division slats aided greatly in firmly holding the oxygen bottles, and yet did not keep out any appreciable amount of light. The inside of each tray was lined with unbleached muslin. A hole of sufficient size

to receive a manila rope was bored through the center of each tray. The trays were then fastened securely to the rope at distances such that when the apparatus was lowered from the rear end of a rowboat into the water, they would be at the following depths; viz., 1 meter, 8 meters, 15 meters, 25 meters and 35 meters. The rope with the trays upon it was held in a vertical position by having an anchor attached to its lower end. The boat was always anchored in water of sufficient depth to keep the apparatus hanging in a vertical position.

Most of the algae for experimental work were used immediately after being secured; however, some were used that had been kept for a few days in a live box of galvanized screen. The live box was lowered into the Sound at a depth which approached that of the natural habitat of the algae. No algae were used which did not appear normal. The pieces of algae used were apparently of equal vigor and were as nearly of the same size as could be obtained. They were also selected from similar growing positions.

All algae used for experimental purposes on a particular day were placed in closed glass fruit jar containing sea water. The jar was wrapped in black oil cloth and suspended in the water of the Sound for at least three hours. This was to make certain that all photosynthesis had stopped as the amount of oxygen consumed in respiration could not be determined if photosynthesis and respiration were going on in the plant at the same time.

Three bottles were used for each depth. Of these one was used as a check, one for respiration, and one for photosynthesis and respiration. Five sets of bottles were used as it was found desirable to make determinations of photosynthesis at five different depths. The depths used were previously stated. The oxygen bottles were filled with sea water in the manner previously described. The ground glass stoppers which had been previously wet in sea water were inserted. The wetting of the stopper prevents the formation of a bubble of air between the surface of water and the stopper. This precaution was followed throughout the work.

All bottles of sea water used as a check were treated in turn as follows: One cc of the  $MnCl_2$  solution was added by means of a pipette which was long enough to reach to the bottom of the bottle.

One cc of the NaOH-KI solution was also added in a similar manner. The wet ground-glass stopper was inserted. The bottle with its contents was now shaken vigorously and stored until the experiments on respiration and photosynthesis were completed.

The remaining bottles of sea water, the algae in a jar of sea water which had been wrapped in black oil cloth, the chemicals, and the apparatus for lowering the bottles which would contain the algae for the experiments on respiration and photosynthesis were placed in a row boat and rowed to a place of suitable depth where the boat was anchored.

The experiments on respiration and photosynthesis were now begun. A sample of alga was removed from the darkened fruit jar and placed in an oxygen bottle which contained the sea water. The bottle was stoppered with a ground glass stopper and then wrapped in black oil cloth.

Another sample of alga was now placed in another bottle of sea water and treated in the same manner except that the bottle was not wrapped in black oil cloth. The two bottles were now fastened securely in a horizontal position in the tray which would hang at a depth of 35 meters when completely lowered. The apparatus for the lowering of the bottles containing the algae had been previously tied to the rear end of the boat and arranged so that the trays could be lowered in the order in which they were to hang from the boat.

The number of each bottle and the time were recorded. The apparatus was lowered until the next tray on the manila rope was reached. Two more samples of algae were now placed in bottles of sea water in the manner just described. These were fastened to the tray that would hang at the next greatest depth, viz., 25 meters. The number of each bottle and the time were recorded. The apparatus was again lowered until the next tray above was reached. This same method was used until the five trays with the bottles containing samples of algae were lowered. The last set of bottles lowered hung at a depth in the Sound of one meter. When one hour had elapsed, this set was raised. The alga was now removed from the bottle of sea water that was to show the amount of oxygen consumed in respiration. One cc of the  $MnCl_2$  solution and one cc of the  $NaOH-KI$  solutions were now added as previously described. The bottles were stoppered, shaken vigorously and placed in a carrying case. The exact time that the experiment had run was recorded. The alga which had just been removed from the oxygen bottle, was now placed in a vial that had the same number as did the bottle from which it had been removed. The alga was now removed from the bottle of sea water that was to show the amount of oxygen resulting when both respiration and photosynthesis were taking place. The chemicals were added and the alga was placed

in a vial which had the same number as did the bottle from which it had been taken. The exact time this experiment had run was also recorded. The apparatus was again raised until the second set of bottles came to the surface. This set of bottles was on the tray which had hung at a depth of 8 meters. This set was treated in the same manner as the previous set. All sets were raised in turn and treated alike.

The method was modified in three different way. In the first modification, the respiration experiment was completed at all depths. Then the experiment in which both respiration and photosynthesis took place was begun. The same samples of alga were used for each depth that had been used for respiration at each corresponding depth. This method required five samples of the alga instead of ten and did away with any possible error due to physiological differences of the samples at each depth.

The second modification was the use of only one sample of alga for the entire experiment. Repeated experiments demonstrated that the amount of respiration did not vary with the depth of the alga in the water. Three respiration experiments were conducted with the same sample of alga. The average of the three experiments was taken as the amount of oxygen consumed by respiration at each depth. The same sample of alga was used for the experiment on photosynthesis and respiration at each depth. It was necessary to reduce the time of an experiment at each depth from 1 hour to  $\frac{1}{2}$  an hour as the intensity of the light varies considerably before 10:00 a.m. and after 2:00 p. m. Since only one sample of alga was used for the entire experiment, all possible error due to physiological differences in the samples was overcome. The method has the disadvantage that there is some variation in the intensity of light between 10:00 a.m. and 2:00 p.m.

The other method used was to utilize two samples of an alga first for respiration, then the same two samples for photosynthesis and respiration at each depth at the same time. The four methods used served as a good check on results.

The remainder of the work was done in the laboratory. When the manganic hydroxid precipitate had settled, the bottle was opened and 2 cc of concentrated HCl was introduced just above the precipitate. The bottle was then closed and shaken thoroughly. Chlorin is set free in the chemical reaction between hydrochloric acid and manganic hydroxid. This reacts with the potassium iodid and iodin is liberated. The amount of iodine set free is proportional to the amount of oxygen dissolved in the water.

The samples were titrated with sodium thiosulphate as soon as all of the precipitate had been dissolved. In titrating, the thiosulphate was added until the color became yellow. Then a small quantity of arrow-root starch solution was added. A sufficient quantity of thiosulphate was now added drop by drop to discharge the blue color. The quantity of thiosulphate solution required was recorded.

The algae placed in the vials were now accurately weighed. All results were made on the basis of 1 gram of alga and one hour of time. Calculations were made by the use of the following formula:

$$\frac{\text{Factor} \times \text{number cc of } \frac{n}{100} \text{ thiosulphate} \times 55.825}{\text{Vol. of bottle}} = \text{cc of oxygen per liter.}$$

The amount of oxygen consumed by respiration was obtained by subtracting the amount of oxygen left in the water after respiration from the amount of oxygen in the water of the check. The amount of oxygen produced by photosynthesis was obtained by adding the amount of oxygen consumed in respiration to the amount of oxygen resulting in the experiment conducted for photosynthesis and respiration.

#### ALGAE USED AND RESULTS

##### *Prionitis lyallii*

This alga has two forms. The water form growing at Argyle is found in water having a depth of about half a meter at low tide. At high tide the water is about three meters in depth. The alga in this locality often reaches a length of  $1\frac{1}{2}$  meters. The thallus is much branched and is often more than 4 cm wide. The other form grows in tide pools. At low tide the depth of the water in these tide pools is from 4 to 10 cm. The alga in the tide pools is densely branched does not become longer than 10 cm, and the width of the thallus is usually less than 1 cm.

Table 1 shows that the greatest amount of photosynthesis, as indicated by the largest amount of oxygen produced, in the water form, occurs at about 8 meters in depth. The greatest amount of photosynthesis in the tide pool form occurs at a depth of about 1 meter,

There is also a lesser amount of photosynthesis taking place in the tide pool form at 35 meters than in the water form at the same depth. In either case the amount of photosynthesis at this depth is very small.

TABLE 1. Showing the number of cubic centimeters of oxygen produced by photosynthesis in *Prionitis lyallii*, under clear sky.

Depth in meters	Water form 8 meters deep at high tide, Argyle				Tide pool form			
				Averages				Averages
1	.344	.395	.693	.477	1.089	1.033	1.001	1.041
8	1.115	1.173	1.242	1.176	.922	1.151	.832	.955
15	.733	1.119	1.032	.961	.918	1.032	.765	.905
25	.181	.717	.631	.509	.765	.369	.310	.481
35	.141	.052	.094	.095	1.01	.087	.042	.071

### *Halosaccion glandiforme*

This alga also has two forms. The low tide form has a greenish red color and is often 10 cm in length. The other form grows on gravel at a depth of 15-20 meters. It has a bright red color and is not over 2½ cm in length.

Table 2 shows that the greatest amount of photosynthesis in the low tide form occurs at about 8 meters in depth while in the deep water form, it occurs at about 20 meters. The effect of rough water in reducing the amount of light entering the water is seen in the last column. The maximum amount of photosynthesis takes place at a depth of 8 meters instead of about 20 meters as the results show when the water is calm. There is also a reduced amount of photosynthesis at all depths.

TABLE 2. Showing the number of cubic centimeters of oxygen produced by photosynthesis in *Halosaccion glandiforme*.

Depth in meters	Low tide form				Deep water form (12-20 meters)				
	Clear sky			Averages	Clear sky			Averages	Clear, but water choppy
1	4.792	4.969	3.864	4.548	5.63	.108	.594	.421	.228
8	5.415	3.692	3.214	4.107	5.09	.159	.475	.381	.361
15	2.834	3.889	3.310	3.344	.671	.403	.406	.494	.194
25	1.002	1.191	1.290	1.361	.714	.408	.364	.406	.115
35	.685	.649	.784	.690	.278	.046	.126	.147	.008



Depth in meters	Clear sky				Averages	Clear sky, Choppy water		Averages	Glendy water, smooth
	1	2	3	4		1	2		
1	1.550	1.044	.684	.334	.399	2.280	2.045	2.180	1.889
5	2.449	2.360	2.440	.884	1.155	2.191	1.796	1.993	1.944
15	2.238	1.863	2.189	1.602	1.966	1.830	.801	.915	.783
25	.806	.334	.686	.604	.447	.426	.181	.340	.301
35	.404	.114	.678	.304	.638	.136	.068	.108	.122

*Rhodomenia pertusa*

This alga is found most abundantly at a depth of 15-20 meters. Table 5 shows that the maximum amount of photosynthesis takes place at a depth of about 15 meters. During cloudy weather, the maximum amount of photosynthesis takes place at a depth of 8 meters. Here is also a reduced amount of photosynthesis at all depths when the weather is cloudy.

TABLE 5. Showing number of cubic centimeters of oxygen produced by the photosynthesis in *Rhodomenia pertusa*.

Depth in meters	Clear sky				Averages	Cloudy			Averages
1	622	251	540	811	556	1 442	1 532	1 487	
8	1 352	593	1 663	1 034	1 223	1 213	1 890	1 551	
15	2 134	1 821	2 594	2 116	2 111	1 134	1 772	1 453	
25	3 125	1 944	1 982	1 253	2 076	927	823	876	
35	741	661	724	921	761	473	281	377	

*Fucus evanescens*

This alga grows largely between low and high tides. Table 6 shows that the maximum amount of photosynthesis takes place at a depth of 1 meter. Cloudy weather does not affect the depth at which the maximum amount of photosynthesis takes place, but there is a reduced amount at all depths.

TABLE 6. Showing the number of cubic centimeters of oxygen produced by photosynthesis in *Fucus evanescens*.

Depth in meters	Clear sky				Averages	Cloudy			Averages
1	3 179	3 429	3 625	4 170	3 605	2 762	1 963	2 213	2 322
8	2 894	3 001	2 587	3 251	2 925	1 340	941	1 432	1 237
15	1 873	2 540	1 463	2 482	2 339	624	422	419	466
25	1 731	1 805	1 168	1 610	1 579	329	119	265	227
35	772	770	687	473	676	111	013	109	077

*Nereocystis luetkeana*

This grows in deep water, but reaches the surface and is held in that position by the cyst. Table 7 shows that the maximum amount of photosynthesis takes place at 1 meter in depth. The only effect of choppy water or of cloudy weather is to reduce the amount of photosynthesis at all depths.

TABLE 7. Showing the number of cubic centimeters of oxygen produced by photosynthesis in *Nereocystis luetkeana*.

Depth in meters	Clear sky			Averages	Clear, water choppy	Cloudy
1	1 154	1 364	1 393	1 370	966	864
8	1 019	1 009	1 113	1 043	763	533
15	782	781	763	778	413	401
25	669	356	348	191	102	088
35	072	134	121	109	036	043

*Costaria costata*

This plant grows somewhat below the low tide. Table 8 shows that there is slightly more photosynthesis taking place at 8 meters than at 1 meter in depth. The effect of cloudy, rainy weather is only to reduce the amount of photosynthesis at all depths. Very little photosynthesis takes place below 25 meters.

TABLE 8. Showing the number of cubic centimeters of oxygen produced by photosynthesis in *Costaria costata*.

Depth in meters	Clear			Averages	Cloudy, rainy
1	2 983	2 349	2 451	2 365	2 532
8	2 875	2 946	3 012	2 998	2 967
15	2 041	2 137	2 018	2 163	2 069
25	836	724	643	596	649
35	191	008	014	130	085

*Desmarestia ligulata*

This is a brown alga found in water from 10 to 25 meters in depth. It is unlike the other brown algae in that the depth at which its maximum amount of photosynthesis takes place is 15 meters. In this it agrees with the majority of the red algae. The effect of cloudy weather or of choppy weather also agrees with the effect of similar conditions upon the red algae.

TABLE 9. Showing the number of cubic centimeters of oxygen produced by photosynthesis in *Desmarestia ligulata*.

Depth in meters	Clear sky			Averages	Cloudy, raining	Clear, somewhat choppy
1	406	308	390	349	146	123
8	519	525	535	571	137	1 013
15	967	1 123	1 123	1 006	023	808
25	943	324	335	360	084	413
35	139	120	084	112	083	043

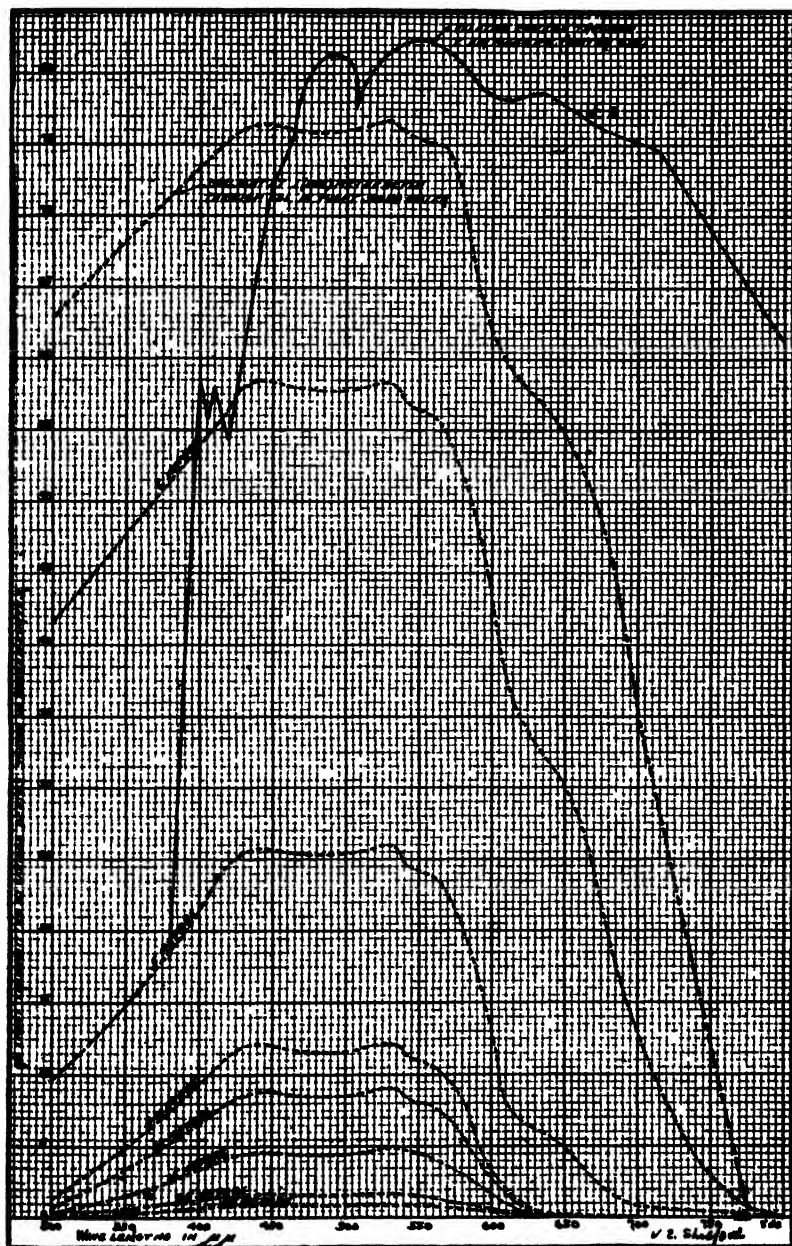


PLATE 31

Plate 31 contains curves showing the percent of light at the various depths used in this study; viz., 1, 8, 15 and 25 meters. Line E2 is an energy curve which shows the sun's energy at Washington, D. C., drawn to an arbitrary scale after passing through two air masses (water 1.31). This is approximately the mean for the summer months, 7 a. m. to 5 p. m., see Fig 12, Shelford and Gail (1922). The table also shows how little light penetrates the water to a depth of 15 meters which is the depth at which the maximum amount of photosynthesis takes place for the deep water algae.

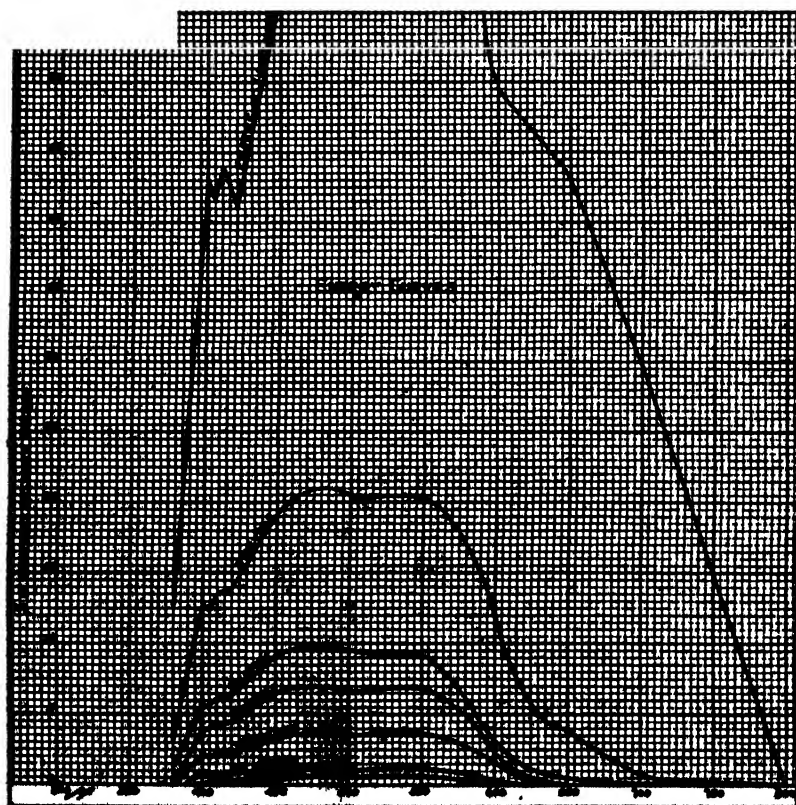


PLATE 32

Plate 32 shows the energy curves for the desired depths. The energy curves are derived by multiplying energy (line E2) by the percent of light at the depths desired for the blue, green, yellow, etc., shown in plate 1. Plate 2 shows that the maximum amount of available energy for photosynthesis lies between wave lengths  $470\mu$  to  $580\mu$ . The dissolved and suspended foreign matter in the water is assumed to be non-selective.

The greatest amount of photosynthesis in the bright red *Halosaccion glandiforme*, in the bright red *Agardhiella tenera*, in *Rhodymena pertusa* and in *Dasyopsis plumosa* occurs at a depth of 15-20 meters as is shown in tables 3, 4 and 5. This is very remarkable since so little light penetrates to that depth, and since there is so little of the sun's energy at that depth, as shown in plates 1 and 2. This, however, is what one might expect, as the habitat of a majority of the red algae at the present time is at a depth of 10-25 meters as is shown in table 15 of Shelford & Gail (1922). It appears as if there must be some other source of energy that can make this possible. Possibly it is due to the red pigment.

The exceptions that the writer encountered are as follows: *Prionitis lyallii* which grows in water not more than 3 meters in depth and in tide pools not more than 10 cm in depth, the low tide form of *Halosaccion glandiforme*, and the form of *Agardhiella tenera* which grows at a depth of 8-12 meters. None of these excepted plants have a bright red color but are brownish red or maroon. The maximum amount of photosynthesis occurs at a depth of 1 meter for the first two of these exceptions; viz., *Prionitis lyallii* and *Halosaccion glandiforme*. The maximum amount of photosynthesis in the third exception, *Agardhiella tenera*, occurs at a depth of about 8 meters. Plate 2 shows how much more available energy there is at 8 meters than at 15 meters and also how very much more available energy there is at one meter than at 8 meters. The photosynthesis in these exceptions is very much reduced at 15 meters, while in the bright red forms of the same genera and species, it is at its maximum at 15 meters in depth. It seems probable that the red pigment absorbs energy that the algae could not otherwise obtain.

Plate 33 shows in graphic form where the maximum and minimum amount of photosynthesis occurs in *Dasyopsis* and *Prionitis*. It shows also that the depth at which the maximum amount of photosynthesis takes place is nearer the surface of the water in cloudy weather with smooth water, or when the sky is clear but the water choppy, in algae

## PHOTOSYNTHESIS AT VARIOUS DEPTHS.

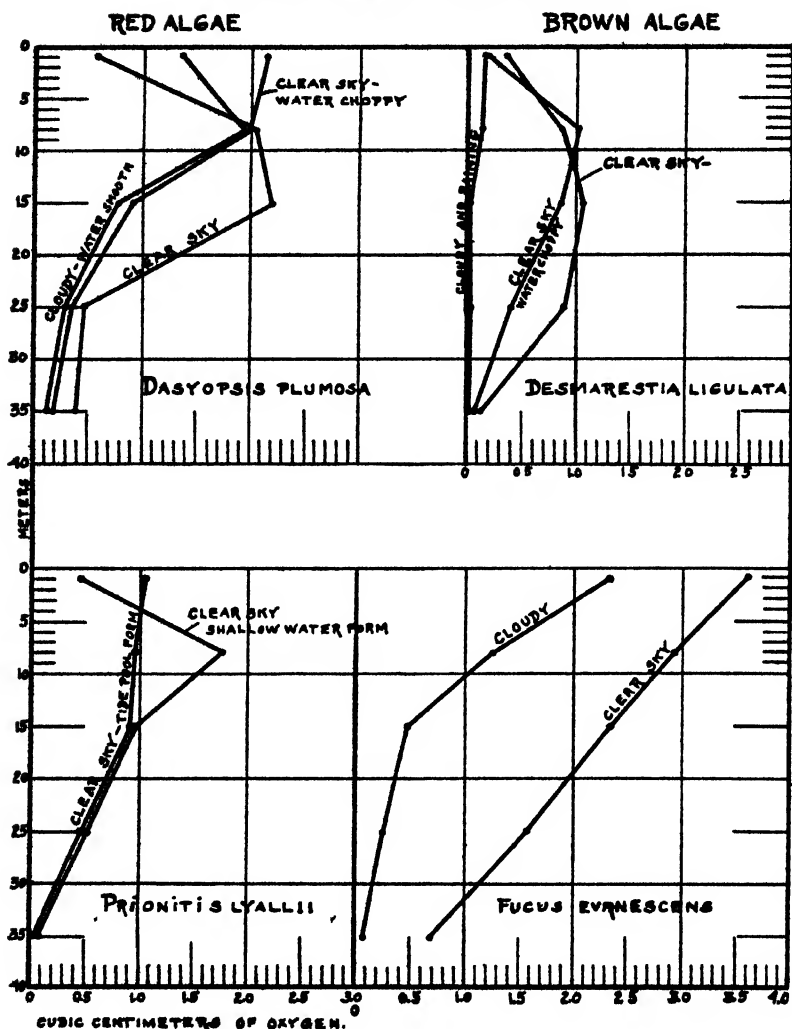


PLATE 33

that in clear weather and smooth water have their maximum amount of photosynthesis below the surface of the water. The brown algae, with few exceptions, seem to require a greater amount of light than do the majority of the red algae. This is shown by the location of their habitat and by the fact that their maximum amount of photosynthesis occurs at a depth of 1-8 meters; *Fucus evanescens* and

*Nereocystis luetkeana* have this maximum at 1 meter and *Costaria costata* and *Laminaria* sp. at 8 meters. Plate 2 shows that the available energy for the brown algae is much greater than it is for the red algae.

*Desmarestia ligulata* is the one exception which the writer encountered but there are probably others. This alga has its habitat at about 15-25 meters as do many of the red algae. The maximum amount of photosynthesis takes place at a depth of about 15 meters. The effect of cloudy weather or choppy water is the same on this brown alga as it is on the majority of red algae. Plate 33 shows graphically where the maximum and minimum amount of photosynthesis takes place in *Desmarestia ligulata* and *Fucus evanescens*. It also shows that cloudy weather and smooth water, or choppy water and a clear sky, does not alter the depth at which the maximum amount of photosynthesis occurs in these algae which have their maximum at a depth of 1 meter or less, but it does show that the amount of photosynthesis is reduced at all depths. The same plate also shows how similar are the photosynthetic curves of *Desmarestia ligulata* ( a brown algae) to corresponding curves of *Dasyopsis plumosa* and other red algae. The plate shows also that it is affected in a similar manner by cloudy weather and by choppy water. This is one of the exceptions among the brown algae. It is a well known fact that other brown and red algae become wilted in appearance, and that they lose their normal color when placed in the same vessel with *Desmarestia ligulata* when in the sunlight where they come in contact. This and its ability to carry on its maximum amount of photosynthesis at a depth of 15 meters are interesting phenomena.

#### SUMMARY

##### *Red Algae*

1. When the sky is clear and the water smooth, the maximum amount of photosynthesis; (a), in *Dasyopsis plumosa* and *Rhodymenia pertusa* is at a depth of about 15 meters; (b), in *Halosaccion glandiforme* and *Agardhiella tenera*, when growing at depths of 15-25 meters, is at a depth of about 15 meters; (c), in *Halosaccion glandiforme*, when the alga is growing at about the zero tide line, is at a depth of about 1 meter; (d), in *Agardhiella tenera*, when growing at a depth of 6-12 meters, is at about 8 meters; (e), in *Prionitis lyallii*, in the tide pool form, is at about 1 meter, and in the shallow water form, at about 8 meters.

2. It seems probable that the ability of the deep water forms to



carry on the maximum amount of photosynthesis at a depth of about 15 meters, where the energy of the sun is so low, is due to the presence of the red pigment.

### *Brown Algae*

3. The maximum amount of photosynthesis in *Fucus evanescens* deeper red algae in habitat and in the depth at which the maximum photosynthesis occurs.

4. The maximum amount of photosynthesis in *Costaria costata* and in *Laminaria* sp., which grow below a zero tide, is at a depth of about 8 meters.

5. The maximum amount of photosynthesis in *Desmarestia ligulata* is at a depth of about 15 meters; thus this plant is similar to the deeper red algae in habitat and in the depth at which the maximum photosynthesis occurs.

6. Reduced amount of light and consequently reduced amount of energy, brought about either by cloudy weather or by choppy water or by both, causes the depth at which the maximum amount of photosynthesis takes place to be nearer the surface of the water in both the red and the brown algae studied, when their habitats are 3 meters or more below the surface of the water.

7. The maximum amount of photosynthesis in the brown algae takes place at a depth of 1-8 meters. *Desmarestia ligulata* is one of the few exceptions.

8. The maximum available energy for photosynthesis at all depths lies between wave lengths  $460\mu\mu$  and  $580\mu\mu$  (see plate 32).

9. When algae grow at the surface of the water as does *Nereocystis*, or between high and low tide lines, the amount of photosynthesis is merely reduced at all depths,

10. The results obtained in this investigation indicate that there is a rather definite relation existing between the habitat of the marine algae and the depth at which the maximum amount of photosynthesis takes place, at least in these algae studied.

11. In Puget Sound 35 meters of depth is about the lower limit at which photosynthesis takes place, in both the red and the brown algae.

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# A Biochemical Study of Pacific Coast Salmon With Particular Reference to the Formation of Indol and Skatol During Decomposition<sup>1</sup>

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<sup>1</sup> This investigation was made at the University of Washington in connection with other problems affecting the salmon canning industry.

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## 1. THE SALMON CANNING INDUSTRY

The value and importance of the salmon canning industry will be realized from a study of the following brief table summarizing the number of cases of salmon packed since the inception of salmon canning on the Pacific Coast in 1864. This table gives the total cases packed for the whole Pacific Coast, including British Columbia, and, for the sake of brevity, is given in ten-year periods, with the exception of the first period which covers only eight years.

TABLE 1. *Volume of canned salmon since the inception of the industry.*

Period		Cases <sup>a</sup>
	1864-1871	504,000
	1872-1881	5,013,861
	1882-1891	11,709,915
	1892-1901	26,864,515
	1902-1911	43,244,258
	1912-1921	73,377,223
Total	1864-1921	160,713,772

In addition to the salmon which are canned, millions of salmon are preserved each year in various other ways, such as drying, salting and freezing. However, more are canned than are preserved in all other ways combined.

Five species of salmon are found in the Pacific Ocean, all belonging to the genus *Oncorhynchus*. The Atlantic salmon belongs to a distinctly different genus, the genus *Salmo*. The Pacific salmon are found along the whole north semicircle of coast from central California to central Japan, and some of them have been successfully introduced into the southern hemisphere, particularly in New Zealand. Each of the five species is known by its scientific name, and by several common names, as shown in table 2.

These five species vary greatly in size, ranging from 3 pound (1.4 kg) pinks and sockeyes to 100 pound (45 kg) kings. The average weight is about as follows: Pinks 5 pounds (2.3 kg), sockeyes 5 (2.3 kg), chums 9 (4 kg), medium reds 10 (4.5 kg), and kings 30 (13.6 kg). They vary somewhat in habit and life history but all are alike in one essential particular,—they are anadromous, that is, when they reach maturity each species comes surging in from the sea to some fresh water stream or lake to spawn, after which practically all

<sup>a</sup>Reduced to a common basis of 48 one pound (454g.) cans to the case. From data given by Cobb (1921).

TABLE 2. *Names of the five species of salmon.*

Scientific name	Puget Sound	Columbia River	Alaska	Other names
<i>Oncorhynchus nerka</i>	Sockeye	Blueback	Alaska Red (Sockeye)	Quinault Redfish
<i>Oncorhynchus tshawytscha</i>	Spring	Chinook	King (Chinook)	Tyee, Quinнат
<i>Oncorhynchus kisutch</i>	Coho Silver	Silver	Medium Red, Coho	Silversides
<i>Oncorhynchus gorbuscha</i>	Pink	Pink	Pink	Humpback
<i>Oncorhynchus keta</i>	Chum	Chum	Chum	Keta, Dog, Calico

of them die and thus complete their life history. The fertilized eggs after an interval depending upon many factors, hatch, and the young fish spend a certain amount of time in fresh water before going to their ocean home.

The salmon industry depends to a great extent upon this spawning migration, for it is only at this time that the salmon may be caught in quantity, and indeed three of the species are almost never caught at any other time. Coming in from the open sea in immense schools they fall an easy prey to various types of nets, to traps and even to hook and line. The fish caught in nets or by hook and line (trolling) are taken into the fishermen's boats and often are transferred to cannery tenders. After reaching the cannery they are unloaded either by sluicing with water into elevators or by pitching with one-tined forks called pughs.

A few of the canneries dress or "butcher" the fish by hand but in most plants a machine known as the "iron chink" is used. This machine removes the head, tail, fins and viscera, and cleans the body cavity by means of brushes and jets of water. The salmon are then "slimed" by hand or by machine. In this process the blood, slime, loose membranes, etc., are removed with knives, spoons, or machines consisting of brushes revolving under jets of water. The cleaned fish are then cut into slices suitable for the different sized cans, either by a rotary hand-cutter or by "gang knives" consisting of revolving disks. The cans, already salted to the extent of  $\frac{1}{4}$  ounce (7.1 g) of dry salt per 1 pound (454 g) can, are filled by hand or machine. A recent type of filling machine cuts the fish into slices, salts the cans and fills them at the rate of 115 to 125 per minute. Many of the flat cans are filled by hand; this is particularly true of the chinook

and sockeye salmon. The filled cans are often weighed by hand or machine, and are inspected to see that they have no bones or skin showing on top.

After filling, the cans are usually run through an "exhaust box" filled with live steam, in which the contents of the cans becomes heated and the air is replaced by steam to a certain extent. This may be done before the tops are placed on the cans, but in most canneries the top is first lightly clinched on by machinery to prevent particles of fish from getting out and water of condensation from getting in. In a few canneries the cans are exhausted by air pumps in the "vacuum closing machine." The primary object of exhausting the cans is to produce a vacuum which will keep the ends concave under changing conditions of temperature and altitude. The hot cans from the exhaust pass immediately to the "closing machine" (or "double seamer") which rolls the tops on very firmly, making the cans air tight. The cans, still hot, are placed in trays ("coolers"), stacked on a car and the car pushed along a track into a retort for cooking with live steam. Pound (454 g) cans of salmon are cooked ("processed") usually for 90 minutes at 117° C. (242° F.) or over; half pound (227 g) cans a few minutes less. The processing has several objects; to cook the fish and make it palatable, to soften the bones, and to render it sterile by killing all living organisms within the can. The pre-heating received in the "exhaust box" materially shortens the time necessary for sterilization.

After processing, the cans are run through a "lye bath" to remove oil and grease and are then thoroughly washed with water and set aside to cool. Leaky or defective cans are detected by tapping the bulging ends with a spike or metal rod; the difference in sound is a sure test for leaks. After cooling, the cans may be lacquered and either stacked in piles, or immediately labeled and placed in cases of 48 cans each.

Fish are very delicate, easy to injure and very easily decomposed. They must be handled as expeditiously as possible and should be in the cans within 48 hours after they are drawn from the water. There are many opportunities for spoilage between the time of catching and of canning. Salmon caught in gill nets soon suffocate, and if not promptly taken from the nets will become somewhat soft. They may be left in small boats for a day or more before the boat arrives at the cannery or at the cannery tender.

The fish are frequently transferred from one boat to another, to the tender and to the cannery by pitching with one-tined forks. Each

time they are thus pugged, bacteria are introduced deeply into the hitherto sterile flesh, and from these centers of infection the bacteria rapidly penetrate in every direction.

Salmon caught by seines are hauled into the boats alive but are frequently placed in deep holds to such a depth that the bottom fish are badly crushed and softened, and spoil very rapidly, particularly since the holds are usually warm and unventilated. A long haul to the cannery under such conditions results in considerable spoilage. A better practice is to place the fish in bins either in the hold or on the deck to a depth of only two feet (61 cm). Separating the fish in bins reduces the sliding about and bruising. If the fish are placed on the deck they should be covered with boards or tarpaulins as a protection from the sun.

Salmon caught by hook and line as in trolling are usually fish which are still feeding, that is, they are either not very far advanced on the spawning migration or are immature; mature salmon, reaching brackish or fresh water, seldom eat anything more, and thus the digestive tract is usually empty and free from bacteria. Fish caught by trolling, with food in them, deteriorate very rapidly; the bellies in time becoming so soft that they break through, a condition known as "belly-burning." A peculiar thing about such fish is that although their appearance may be very poor they may have no odor of decomposition, and in frequent chemical tests we found neither indol nor skatol. It is probable that the softening and the breaking down of the tissues is due not to bacterial decomposition but to the action of the enzymes in the digestive juices. Salmon caught by trolling should therefore be cleaned at once and if possible placed on ice.

Salmon caught in traps are brailed alive into boats or scows and should reach the cannery in good condition if the traps are not located too far away and if the boats are not delayed by bad weather. Even if the fish reach the cannery in first class condition there may be a considerable delay due to an over supply or to a break-down in the machinery. It is apparent, therefore, that in handling so perishable a commodity as fish there are many opportunities for spoilage, and the excellent condition in which the bulk of the canned salmon reaches the market speaks well for the care and resourcefulness of the average packer.

All of the conditions and practices which I have mentioned leave their mark upon the fish, and this record may be read in the canned product by the experienced examiner.



## 2. EXAMINATION OF COMMERCIAL CANNED SALMON

After the salmon has been canned it is very likely to be examined at least once before reaching the consumer. Brokers may buy a parcel of several thousand cases on the reputation of the packer but they are more likely to stipulate that the parcel be examined either by themselves or by some one in whom they have confidence. Little or no attempt has been made to grade canned salmon as is done with butter, cheese and many other foodstuffs. The only grading has been by the species and the district where packed. This is very unsatisfactory. If grading is ever placed on a scientific basis it will be by means of carefully kept records covering all species and districts. To obtain these records a systematic method of examination covering everything which is significant regarding the workmanship on the parcel and regarding the quality and condition of the fish must be followed. Partly as the result of the study of the five species of salmon, which is described in the experimental part of this thesis, and partly as a result of the careful examination of several thousand cans of commercially canned salmon, the following systematic method for the examination of canned salmon was evolved.

### A. *Systematic method*

*Description of the parcel.* This should include the species of salmon, brand or label, packer, cannery, size of can, can mark, case mark, number of cases in the parcel, and location of the parcel.

*Sampling.* In canned salmon this is unsatisfactory at best. A parcel of 1,000 cases, containing 48,000 cans, may represent a cross section of the cannery's entire season's output ranging in extreme instances from very good to very bad. One case may even represent several days' canning. Under these conditions no systematic method of sampling can be carried out. Each case should be stamped with the date of packing, then if unsatisfactory fish are found a segregation can be made. All that can be done in sampling is to attempt to get a representative sample by taking one or two cans from a number of cases situated in all parts of the parcel. Ninety-six cans are usually drawn in this manner in parcels of 1,000 cases, and an increasingly smaller proportion from increasingly larger parcels. When the cases are opened for sampling they should be inspected for swollen or rusty cans and for thoroughness of lacquering and labeling.

*Examination of the sample.* This may be undertaken from five different viewpoints: (1). Bacteriological examination. (2). Workmanship in packing; including the vacuum, cleaning, filling, cooking,

salt, pugh marks and net weight. (3). Quality of the fish when caught; here considering the oil, amount of liquid, color and "fresh water marking" on the skin. (4). Condition of the fish when canned; involving odor, texture, reddening, "honeycombing" and turbidity of the liquid. (5). Chemical examination. These are considered in order below.

*Bacteriological examination.* From 24 to 48 cans are examined for living organisms. The cans are carefully cleaned and a gas flame is directed upon the top until all the moisture has been driven away and the lid thoroughly heated. The heating is not continued long enough to scorch the fish inside, however. After waiting a few minutes for the cans to cool, the vacuum is determined by means of a vacuum-pressure gauge. A hole is then made in the end near the seam by means of a hot, pointed, iron rod having a diameter of about 6 mm. ( $\frac{1}{4}$  inch). By means of a sterile pipette, about 1 cc. of the liquid and finely divided particles of fish are transferred to a Petri dish and standard agar added. In a few cases 1 cc. of the liquid is also placed in anaerobic media. If any living organisms are found they are carefully examined to determine their nature. The presence of non-spore-formers indicates either a leaky can or contamination of the culture, the rigorous cooking to which salmon is subjected precluding the possibility of their survival. After the bacteriological sample has been taken the top of the can is cut off just below the seam and the liquid drained into a 15 cm. (6-inch) white enameled pan and poured into a graduated cylinder. The solid portion of the fish is then examined.

*Vacuum.* This is determined by means of a compound vacuum-pressure gauge equipped with a piercing point and a rubber gasket. A can should have sufficient vacuum, 8 inches (20.5 cm.) or more, to keep the ends concave under all conditions of temperature and altitude. Cans with tight seams will usually have some vacuum due to the absorption of oxygen by the salmon. Cans without vacuum will usually be found on close examination to have loosely rolled seams, a leak in the seam, or occasionally a small hole through the tin plate.

*Cleaning.* No pieces of the gills, fins or intestines should be found in the can. All clotted blood which could be removed without tearing the flesh should have been washed out.

*Filling.* There should not be more than three pieces of fish in the can and the long axis of these should parallel the long axis of the can. The ends of these pieces should be clean-cut, not jagged.

*Cooking.* This is judged as sufficient or insufficient according to the friability of the bone. If vertebrae are present these are pressed between the thumb and fingers to determine this point. In the absence of vertebrae the brittleness of the smaller bones is tested. Insufficient cooking as determined by this method does not necessarily mean that the cans are not sterile, nor does a soft, easily friable bone insure sterility. This test is much used in the salmon industry, however, and is a useful indication.

*Salt.* No definite amount can be stated since some people prefer more than others. However, there should be a definite salty taste.

*Pugh marks.* If fish are pughed before the blood in them has clotted, blood clots are formed along the puncture and may be found in the canned fish. They detract from the appearance of the pack and are an evidence of careless handling of the fish.

*Net weight.* The food and drug law of the United States, as amended, requires that every package of food be correctly marked with the net contents. Several cans are weighed and the average net weight calculated.

*Oil.* After the liquid has been standing in the graduated cylinder for a few minutes the oil rises to the top and the amount may be measured. When the fish begin their spawning migration they are usually fat, but since they no longer feed, this stored fat is gradually used up and the fish become poorer in quality. In deciding whether the oil in a can is good, average or poor, one must take into account the species, the section of the fish included in the can and the length of time the fish has been packed, since each of these factors has an effect on the amount of free oil in the can.

*Amount of liquid.* The total amount of liquid, including the oil, is measured and recorded. As the fat in a living fish decreases the amount of water increases; therefore, if a large amount of liquid is found in the can the fish is likely to be of inferior quality. The character of the liquid is recorded as normal, slightly turbid or turbid. The liquid in cans containing badly decomposed fish may be "milky" in appearance.

*Color.* Each species of salmon has its own characteristic color of the flesh, ranging from a deep red in the sockeye to a pure white in the white king. To a certain extent this color is modified in cooking, the degree of change varying with the different species. Furthermore, the amount of color within each species varies greatly with the

stage of the spawning migration at which they are caught, since the color gradually fades as one of the physiological changes of this period. During decomposition the natural color of the cooked fish also appears to fade gradually. The color of the cooked fish is expressed as good, average and poor, for that species.

*"Fresh water marking" on the skin.* The skin of a salmon which is on the spawning migration takes on various colors, some of them very bright. Jordan and Everman (1896) speak of these colors as the "nuptial dress," but in the trade they are known as "water marks," since they usually become noticeable after the fish have reached brackish or fresh water. Distinctly "water-marked" fish are nearly always inferior to those which do not have these colors.

*Odor.* This is one of the most reliable indications of decomposition and is usually the factor which decides whether a can of fish shall be condemned as unfit for food. In smelling the salmon it is first broken up between the hands and then held very close to the nose. The following terms, good, stale, tainted and putrid are the terms used in describing the odor. Fish which are canned while very fresh possess a normal fish odor. Fish canned when very slightly stale do not have this normal odor nor do they have a definite odor of decomposition. Both of these are recorded as good. Fish canned when stale will have abnormal odors, with a slight odor of decomposition, which usually leaves the fish during exposure to the air for a few minutes. These are recorded as stale, and are regarded as of poor quality but not unfit for food. Fish canned when tainted will have an unmistakable odor of decomposition, which persists in the fish even after exposure to the air for a few minutes. These are recorded as tainted and are regarded as unfit for food. When the odor of decomposition is very pronounced and offensive, apparent as soon as the can is opened, the odor is recorded as putrid. There are some odors which are encountered in canned salmon which, while abnormal, do not appear to be due to decomposition. Such an odor is found in "water marked" chum salmon.

*Texture.* Each species when packed fresh has its own degree of firmness. Fish which are stale or tainted before canning have a texture which is more or less soft, and the degree of softness corresponds roughly to the amount of decomposition in the fish, however this must be interpreted with care since this texture is also affected by the fatness of the fish.

*Reddening.* This is an important indication of spoilage. The flesh

of raw salmon takes on a feverish appearance, which persists through the processing; but when the can is opened the unnatural color will be found to be unevenly distributed and will fade quickly. It can thus be distinguished from the true color of the fish.

*"Honeycombing."* The canned product sometimes has small holes in the flakes which may extend entirely through them. It is probable that these holes are a result of the gaseous condition of the partially decomposed flesh before canning. When a piece of this "honey-combed" flesh is placed on the end of the tongue a distinct biting taste is experienced similar to the "bite" of strong cheese.

*Turbidity of the liquid.* The liquid in cans of salmon is, of course, always somewhat turbid, when the fish is stale or tainted before canning the turbidity is increased. Rough handling and very low temperature in the cans under examination may also result in a turbid liquid.

*Chemical examination.* Cans which have been classed as strongly stale by physical appearance and odor may be examined chemically for indol and skatol to determine whether they should be condemned as unfit for food. Cans which are good, slightly stale or tainted, as determined by odor, need not be examined chemically as their status is already well established by the preceding tests.

After carefully examining 48 cans (more for large parcels) according to the scheme outlined above, aided by an accurate record on forms similar to those in Fig. 1, the examiner is in possession of sufficient data to enable him to report on the thoroughness of the workmanship in packing the parcel, the quality of the fish when caught, their condition when canned and the adequacy of the cooking process.

### 3. CHEMICAL COMPOSITION OF FISH FLESH

One of the earliest investigators of the constituents of fish flesh was Morin, who in 1822 published his work on the composition of the smelt. Payen in 1854 determined the fat, protein, ash and water in the herring and the salmon. Several other chemists, among them Koenig (1876), Buckland (1874) and Almen (1887) also made similar analyses. The results obtained by them have been reviewed in detail by W. O. Atwater (1888) and recalculated to a common basis. The results which he and they obtained on salmon are given in table 3. The species is presumably the Atlantic salmon, *Salmo salar*.

NATIONAL CANNERS ASSOCIATION PACIFIC COAST INVESTIGATIONS LABORATORY REPORT OF EXAMINATION OF CANNED SALMON														
No.	Brand	Can No.	Can Date	Can Mark	Can Use	Can Date	Can Mark	Can Use	Can Date	Can Mark	Can Use	Can Date	Can Mark	Can Use
<p><b>CHEMICAL EXAMINATION</b></p> <p>Sample from by _____ Date drawn _____</p> <p>Can opened _____</p> <p>Inspected _____</p> <p>Reinspected Each _____</p> <p>Condition of Can _____</p> <p>Oil _____</p> <p>Liquid _____</p> <p>Other _____</p> <p>Tastes _____</p> <p>Smelling of Fish _____</p> <p>Fish Water Boiling on Stove _____</p> <p>Cooking in _____</p> <p>Chemical _____</p> <p>Phosphorus _____</p> <p>Color _____</p> <p>High % _____</p> <p>Low % _____</p> <p>Remarks _____</p>														
<p><b>BACTERIOLOGICAL EXAMINATION</b></p> <p>Sample from by _____ Date drawn _____</p> <p>Can opened _____</p> <p>Inspected _____</p> <p>Reinspected Each _____</p> <p>Condition of Can _____</p> <p>Oil _____</p> <p>Liquid _____</p> <p>Other _____</p> <p>Tastes _____</p> <p>Smelling of Fish _____</p> <p>Fish Water Boiling on Stove _____</p> <p>Cooking in _____</p> <p>Chemical _____</p> <p>Phosphorus _____</p> <p>Color _____</p> <p>High % _____</p> <p>Low % _____</p> <p>Remarks _____</p>														

Fig 1. Form used in examination of canned salmon.

TABLE 3. *Composition of the salmon.*

Year	Author	Water	Solids	Albuminoids	Fats	Ash	Protein N x 6.25
1854	Payen.	75.70	24.30	18.17	4.85	1.28	
1874	Buckland.	77.06	22.94	10.11	7.11	2.07	
1887	Almen.	70.33	29.67	18.06	10.12	1.49	19.39
1888	Atwater.	63.61	36.39	21.60	13.38	1.41	22.39

A considerable variation in composition will be noticed in table 3, which is probably due in large part to the seasonal changes in composition. Recent work by Clark and Almy (1918), Green (1919) and Dill (1921) has shown marked changes in several species of fish, especially at the spawning period. The principal variations are in the fat and water percentages which are inversely related to each other. The protein and ash percentages do not change to any great extent. A few examples are given in table 4.

TABLE 4. *Seasonal variation in the composition of fish.*

Author	Fish	Date	Water	Fat	Protein	Ash
Clark and Almy	Butterfish	May 19	74.34	5.96	18.06	1.49
Clark and Almy	Butterfish	Oct. 12	69.99	13.42	18.25	1.40
Dill	Yellow Fin Tuna	May 14	72.83	1.00	25.37	1.47
Dill	Yellow Fin Tuna	Sept. 8	69.17	6.54	24.00	1.32

Cobb (1921a) gives a number of analyses of Pacific Coast salmon made by Atwater (1888), Langworthy (1898), Knisely (1908), Loomis (1912) and Elliott and Clemens (1916). Most of these analyses represent canned salmon, but Loomis also analyzed a fresh sockeye salmon.

Recently Clark and Shostrom (Date?) have analyzed several hundred cans of salmon representing the five species of Pacific salmon from every important salmon canning district from northern California to the Yukon River in Alaska. The cans analyzed were all prepared from the second cut of an individual fish. This was done because the composition varies in different parts of the fish, and cans from the same part constitute a better comparison than those from different parts. Since this work was done in the National Cannery Laboratory at the University of Washington, Seattle, and has not yet been published, a summary of the results is given in table 5.

TABLE 5. *Composition of Pacific salmon.*

Species	No. individual fish analyzed	Moisture %	Ether <sup>a</sup> extract %	Protein (N x 6.25) %	Total ash %	Salt-free ash %	Calories <sup>b</sup> per pound
Chinook (King)	204	63.53	13.50	19.48	2.85	1.18	931
Sockeye (Red)	130	64.52	10.84	20.67	2.97	1.29	841
Coho	99	66.26	9.47	20.40	3.15	1.22	778
Pink	90	69.24	6.16	20.56	3.47	1.32	642
Chum	120	68.95	7.42	20.83	2.40	1.24	700
Average, all	643	66.50	9.48	20.39	2.97	1.25	778

Fish flesh consists of protein, fat, water, mineral matter and a very small percent of carbohydrates. The composition of such fat fish as the Pacific salmon compares very well with the meat of mammals, but in general fish flesh is higher in water and lower in fat than other flesh and in consequence has a lower fuel value. However, eaten with carbohydrate foods, a balanced diet is obtained equal in fuel value and muscle building power to a similar diet containing other flesh. Recent unpublished work by Barton and McMillan (Date?) indicates the presence of a very small amount of carbohydrate material in salmon flesh.

The elementary composition of fish flesh was determined by Koenig and Splittgerber (1909) and compared with meat. Osborne and Heyl (1908) compared the hydrolytic products of halibut muscle with those of chicken muscle. Okuda (1919) has determined the cleavage products of both ordinary flesh and "chiai" flesh of the bonito, *Katsuwonus pelamis* (table 6). The "chiai" flesh is the blood-colored flesh (dark meat) which occurs to a certain extent in the lateral muscle of most fish. The two kinds of flesh were separated as completely as possible and subjected to hydrolysis with mineral acid. Results are given in per cent of the ash and moisture-free muscle substance.

Okuda, Okimoto and Yada (1919) have published similar work on the whale and the cod; Okuda, Uematsu, Sakata and Fujikawa (1919), and Okuda (1919a), on the spiny lobster and the cuttlefish.

A great deal of disagreement occurs in the literature as to the amount of the different bases and amino-acids which are present in

<sup>a</sup>This represents fat.

<sup>b</sup>Calculated by the factors of Rubner: 18.6 Calories for 1 percent protein, and 42.3 Calories for 1 percent fat, on the basis of 1 pound (454g).



TABLE 6. *Products of hydrolysis of "chiai" and ordinary fish muscle.*

	"Chiai" muscle	Ordinary muscle
Alanin -----	1.1	2.3
Valine -----	1.8	2.8
Leucine -----	9.2	10.4
Proline -----	3.0	3.1
Phenylalanin -----	1.6	4.1
Aspartic acid -----	3.2	3.3
Glutaminic acid -----	12.1	8.1
Tyrosine -----	2.9	2.1
Arginine -----	7.08	7.8
Histidine -----	3.16	3.04
Lysine -----	6.78	7.41
Tryptophane -----	Present	Present
Glycocoll -----	Not found	Not found
Serine -----	?	?
Ammonia -----	0.78	0.64
Guanine -----	0.12	0.09
Adenine -----	0.1	0.04
Hypoxanthine -----	0.03	0.08
Xanthine -----	?	?
Creatine -----	0.29	0.44
Methylquanidine -----		0.005
Taurine -----	0.34	
Creatinine -----	Present	Present
Inosinic acid -----	.013	.043
Lactic acid -----	.067	.062

fish flesh. The methods used are rather difficult to carry out, and inexact, and it may also be that the amount in the flesh varies from time to time. The following results for creatin and creatinin in the flesh of the salmon will illustrate this.

Author	Creatin <sup>a</sup>	Creatinin <sup>a</sup>
Koenig and Splittgerber (1909) -----	0.027	0.207
Suzuki and Yoshimura (1909) -----	0.320	None
Okuda (1912) -----	1.525	0.182

Cholin, neurin and muscarin have not been isolated from fresh fish, but cholin was found by Bocklisch (1885) in herring brine, and by Mörner (1897) in "surfisk," a pickled, fermented fish product. Betaine has been found in the cuttlefish (Suzuki and Yoshimura 1909), the cod (Yoshimura and Kanai 1913) and the shark (Suwa 1909). Carnosin was found in the dried muscle of several fish, among

<sup>a</sup>Grams per 100 grams of dried fish.

them salmon (0.055%), by Suzuki and Yoshimura (1909). Urea has been found in large amounts in the muscle of several fish, notably the dogfish and skate (Benson 1920), while work in our laboratory indicates that the flesh of the barracuda, and the atka fish (from the Aleutian Islands) also contains urea. Taurin (Suzuki and Yoshimura 1909) and lactic acid (Liebig 1874) have also been found in small amounts, while according to Schondorff and Wachholder (1914) the glycogen content of fish muscle varies from 0 to 0.59%. The carp at death was found to have 0.527%, after one hour 0.359%, after one day 0.145%, and on the third day none. The muscle of fresh salmon and cod contained none. In fish livers the glycogen varied from 2.5 to 12.94%.

Oils are obtained both from the flesh of fish (fish oil) and from the liver (liver oil), but those fish which contain large amounts of fat in the liver have a small percentage of fat in the flesh. Little is known as to the composition of these oils. Stearic and palmitic acids, according to Lewkowitsch (1914), have been isolated from cod liver oil, but no oleic acid was found. Highly unsaturated acids are present but these are not identical with linolenic. Heyerdahl (quoted by Lewkowitsch 1914) concluded that the mixed fatty acids of cod liver oil contained about 4 per cent of palmitic acid, 20 per cent of jecoleic and 20 per cent of therapeutic acid. Liver oils contain cholesterol and other unsaponifiable matter. Fish oils contain palmitin. The mixed fatty acids contain highly unsaturated constituents which are not identical with linolic or linolenic acids. Tsujimoto (quoted by Lewkowitsch 1914) found clupanodonic acid to the extent of 6 to 9 per cent. Fahrion (1893) is of the opinion that he has proved the presence of jecoric acid in fish oil.

Beal and Brown (1921) have recently made a study of the fatty acids of five commercial fish oils, among them salmon oil. They found evidence of the presence of myristic, palmitic and clupanodonic acids and also for the presence of acids more highly unsaturated and of greater molecular weight than clupanodonic, such as hexadecatrienoic, arachidonic, eicosapentenoic, docosapentenoic, and docosahexenoic.

#### 4. DECOMPOSITION OF FISH FLESH

When any organic material containing albuminous substances, such as fish, is allowed to stand under suitable conditions of moisture and of temperature, it decomposes very rapidly through the agency of enzymes secreted by various bacteria. This special fermentation,

known as putrefaction, differs from natural digestion in that the former yields many products not found in natural digestion, such as gaseous products, mercaptans, volatile acids, aromatic acids, amines, phenol, indol, skatol, and finally ptomaines. It was formerly thought that these products were excreted from the bacterial cells in which they had been formed, but it is now generally accepted that enzymes are secreted by bacteria, and these enzymes split the organic compounds, forming these and other new chemical substances.

Many different species of bacteria may be concerned in a spontaneous putrefaction. Bienstock (quoted by Rettger 1903, 1906) claimed that true putrefaction could be brought about only by obligate anaerobes. Rettger (1906) defined putrefaction as a bacterial decomposition of albuminous matter accompanied by the formation of "Faulnissprodukte." In his earlier work, Rettger (1903) took exception to Bienstock's conclusions, but in later work (1908), using extreme care, his results confirmed those of Bienstock. Effront (1917) states that, "The putrefactive bacteria are ordinarily anaerobic, like *Bacillus putrificus coli*; nevertheless there are also very active ones which are aerobic, like *Bacillus coli communis*." Moreover, the bacterial flora is not the same throughout the putrefaction, some species converting the original proteins into substances which other bacteria can utilize, and frequently forming substances which are injurious to themselves. According to Effront, none of the putrefactive bacteria produce pepsin, but several produce trypsin which converts the albuminoid material into albuminoses, peptones and amino-acids, which are then attacked by erepsin, secreted by other species, and changed into simpler compounds. Finally, amidases come into action and bring about the formation of volatile acids and amines, as well as phenol and indol derivatives.

The following substances are given by Effront as likely to occur in the course of putrefaction in addition to gaseous products ( $\text{CO}_2$ ,  $\text{CH}_4$ ,  $\text{N}_2$ ,  $\text{H}_2\text{S}$ ,  $\text{PH}_3$ ) and residual peptones: "(1) Ammonia and amines; ethylamine, propylamine, and trimethylamine. (2) Volatile acids, comprising all the members of the fatty series up to caproic acid. They are sometimes normal acids, sometimes their isomers; propionic acid is less frequent than the others; formic acid is quite rare; acetic and butyric acid are especially common. (3) Aromatic acids and oxyacids; like phenylpropionic, oxyphenylacetic, and oxyphenylpropionic acids. (4) Phenol, indol, skatol, pyrrol and its derivatives, these bodies sometimes being in very small quantities, or even completely absent. (5) Sulphur derivatives, like methyl-mercaptan. (6) Various amino-acids; leucin, tyrosin, tryptophane, and

sometimes glycin, creatinin, etc. (7) Various ptomaines; like putrescin and cadaverin, the guanidins, cholin and neurin, pyridin, hydrocollidin, etc."

In addition to the products formed by the splitting of nitrogenous compounds, there will also be decomposition products of the fats, consisting of glycerin and various fatty acids. The following reactions show how some of the above substances may be formed during decomposition.

The effect of amidases on amino-acids was studied by Effront (1911), who gives the following reactions: (1). The monobasic acids are transformed into ammonium salts, e.g., glycin with the addition of hydrogen gives ammonium acetate. (2). Betain by the addition of hydrogen and the loss of water is transformed into the acetate of trimethylamine. (3). The polybasic acids undergo a molecular degradation, e.g., aspartic acid by the addition of hydrogen yields ammonium propionate and carbon dioxide.

Tanner (1917) gives three methods by which straight chain acids may be simplified: (1). Deaminization; glycin to acetic acid and ammonia. (2). Decarboxylation; glycin to methylamin and carbon dioxide. (3). Oxidation; acetic acid to carbon dioxide and water. Tanner also shows by reactions the probable steps in the formation of phenol from tyrosin: (a) Tyrosin; (b) parahydroxyphenylpropionic acid; (c) hydroxyphenylacetic acid; (d) paracresol; (e) phenol.

Ehrlich (1909) has shown that amino acids may be fermented into alcohols corresponding to the acids used, ammonium bicarbonate being formed simultaneously. The acids which are thus formed may be very quickly changed to simpler ones; glutamic acid, which probably first forms oxybutyric acid, yields succinic acid as a final product.

Hopkins and Cole (1903) give the following steps in the decomposition of tryptophan by bacteria: (1) Tryptophan; (2) Indolpropionic acid; (3) Indolacetic acid; (4) Skatol; (5) Indol. The decomposition outlined above is the probable source of the indol found in our raw and canned salmon experiments.

Effront (1917) says that tyrosin by the addition of hydrogen may yield methane and ammonium-p-oxyphenylacetate, a reaction which may explain the formation of methane from albuminoid material.

Ornithin may give rise to either amino-valeric acid or to tetramethylenediamine; in the first case by the addition of hydrogen and in the second by the loss of carbon dioxide. Lysin may be transformed to pentamethylenediamine and carbon dioxide. Another ptomaine,

neurin, is derived by loss of water from cholin, which is the constituent base of the lecithins.

According to Mathews (quoted by Tanner, 1919) cystine goes to cysteine, then to thioethylamin and finally to ethyl mercaptan. Tanner (1917) has shown that bacteria can produce hydrogen sulphide from cystine.

Effront (1917) speaking of the gaseous products of putrefaction states that the digestive enzymes (pepsin, trypsin, and erepsin) do not have an appreciable effect on the sulphur contained in albuminoid material, but that putrefaction enzymes split it off in the form of  $H_2S$  and the mercaptans. Methane can arise from the reduction of tyrosin and carbonic acid as a by-product in many of the reactions already given. Ammonia is also a by-product of many reactions. However, as to the mechanism by which nitrogen, hydrogen and hydrogen phosphide are formed, nothing is known. He is inclined to attribute the formation of nitrogen to the reduction of nitrates rather than to albuminoid material.

Effront points out that substances formed early in putrefaction may not be present at later stages. Some of the poisonous substances elaborated during decomposition may disappear later, and it is more dangerous to eat meat just beginning to putrefy than that which is completely decomposed. Duclaux states that phenol and indol may be formed and then decomposed during the course of putrefaction; but Effront states flatly that "when we do not find indol present, it is because it was never formed."

The reactions and data given above show that it is impossible to give a simple and unchangeable scheme for decompositions since "the quality and quantity of the products formed are dependent upon the nature of the acting enzymes, which, themselves, are functions of the species of bacteria present, of the albuminoid substance to be transformed, and also of the physical and chemical conditions of the medium."

Fish flesh, as has been shown, contains most of the amino-acids and other nitrogenous substances just mentioned, and presumably all of the decomposition products listed may be formed from them under suitable conditions. The question arises as to which one of these products can be used to the best advantage as an index of the amount of decomposition in a product such as canned salmon. Ammonia has been frequently used as a measure of decomposition and seems to be fairly satisfactory when dealing with raw materials; but when used with canned products, such as meat and fish, the results show a decidedly disturbing factor, i.e., the ammonia produced by the cooking

process during canning. On account of this factor the investigator of canned meats and fish is left in doubt as to the percentage of the ammonia present in canned goods which is due to the canning process, and the percentage which is due to decomposition before canning. Loomis (1912) determined the "ammoniacal nitrogen" in fresh and canned salmon by two methods and makes the following observation. "As all samples of canned salmon were in good condition and gave no indication of deterioration as far as the senses could detect it, the results on 'ammoniacal nitrogen' are also of interest, being two or more times greater in the case of the canned product than in the fresh fish."

Weber (1921) made an experimental pack of sardines in different stages of spoilage and determined the volatile nitrogen as ammonia and amines both before and after canning. He concludes that, "The cooking received during sterilizing very greatly increased the amount of ammoniacal material in the packed fish." He further states that in the case of fish which had undergone an excessive decomposition his results indicate that the determination of volatile alkaline material may be used to detect this degree of spoilage but that with lesser amounts of decomposition the method is of doubtful value.

Bidault and Couturier (1920) state that the quantity of the ammoniacal compounds in canned meat is a function of the temperature of sterilization.

The amount of free fatty acid undoubtedly increases during decomposition. Weber made a large number of determinations in his work on the sardine, but from the fact that only a few of the results are given in his report, and that these are very inconclusive, we may conclude that little reliance may be placed on the method. No reference was found in the literature to the effect of the canning process on the free fatty acids of canned foods; however, since one of the principal methods of hydrolysis of fats consists in heating the fats under pressure in the presence of steam, it seems highly probable that some of the fat in salmon may be hydrolyzed during the canning process, since all the factors of steam, heat and pressure are present.

Röhmman (1908) states that tryptophan, when heated, gives rise to indol and skatol. Salmon flesh contains tryptophan, and the question arises as to whether the canning process is severe enough to break it down to indol or skatol. Experiments herein recorded prove that no considerable amount of these compounds is formed during the ordinary canning process. In fact, the canning process, as shown

by further experiments, does not appear either to increase or decrease the amount of these compounds already present in partially spoiled salmon. No references were found in the literature as to whether indol or skatol had been found in canned salmon, but work done by Houghton and Hunter (1920) of the U. S. Bureau of Chemistry, published several months after this investigation was initiated, showed that it was frequently present and might possibly furnish a means of detecting spoilage.

From a consideration of the above information relative to ammonia, fatty acids, and indol and skatol, it appeared that the latter were the most promising decomposition products to use as an index of spoilage. It was therefore decided to investigate the presence of indol and skatol in raw and canned salmon, and to attempt to develop a quantitative method of determination which should be available as a check on the organoleptic examination of the latter. Some work was also carried out, using ammonia and fatty acids as indexes of decomposition.

## 5. DEVELOPMENT OF A METHOD FOR DETECTING DECOMPOSITION BY MEANS OF INDOL AND SKATOL

### A. *Selection of suitable color tests*

From a study of the literature relating to the decomposition of nitrogenous matter it seemed that the formation of indol and skatol would form the most accurate index of the presence and progress of decomposition. The next step therefore was to proceed to select a method for the determination of these substances. Owing to the small amount present even in very advanced stages of decomposition, this method must necessarily be based on a color reaction. Fortunately both indol and skatol give very marked colors in extremely minute quantities. Numerous color reactions are recorded in the literature, and among them are the following.

#### Indol

a. *Formaldehyde reaction* (Konto 1906). To 1 cc distillate in a test tube add 3 drops of a 4% formaldehyde solution and 1 cc. of concentrated sulphuric acid. Agitate the mixture and observe the appearance of a violet-red color if indol is present. Konto states that indol may be detected in a dilution of 1:600,000. Skatol gives a yellow or brown color.

b. *Cholera-red reaction* (Salkowski, 1883; Tobey 1906a; Hawk 1918). To 5 cc of the distillate in a test tube add one-tenth its volume of a 0.02 per cent solution of potassium nitrite and mix thoroughly. Carefully run concentrated sulphuric acid down the side of the tube so that it forms a layer at the bottom. Note the purple color. Neutralize with potassium hydroxide and observe the production of a bluish-green color.

c. *Nitroprusside reaction* (Deniges 1908; Hawk 1918). To a small amount of the material under examination in a test tube add a few drops of a freshly prepared solution of sodium nitroprusside,  $\text{Na}_2\text{Fe}(\text{CN})_5\text{NO} + 2\text{H}_2\text{O}$ . Render alkaline with potassium hydroxide and note the production of a violet color. If the solution is now acidified with glacial acetic acid the violet is transformed into a blue.

d. *Nitroso-indol nitrate test* (Hawk 1918). Acidify some of the material under examination with nitric acid, add a few drops of a potassium nitrite solution and note the production of a red precipitate of nitroso-indol nitrate. If the material contains but little indol simply a red coloration will result.

e. *Vanillin-sulphuric acid test* (Steensma 1906; Deniges 1908; Blumenthal 1909; Nelson 1916; Zoller 1920; Weehuizen, (date?). To 5 cc of the solution add 5 drops of 5% solution of vanillin in 95% alcohol, 2.5 cc of concentrated sulphuric acid and mix. If indol is present an orange color will be formed. Test is sensitive to 1 part in 2 million. If skatol is present a violet color will be formed. Test is sensitive to 1 part in 4 million.

f. *Para-dimethylaminobenzaldehyde* (Herter 1905, Steensma 1906; Deniges 1908a; Von Moraczewski 1908; Blumenthal 1909; Baudisch 1915; Nelson 1916; Ingvaldsen and Bauman 1920; Zoller 1920). To 5 cc of solution, add 2 cc of a 2% alcoholic solution of paradimethylaminobenzaldehyde, 10 drops of concentrated hydrochloric acid and mix. After a few minutes, add 1 cc of chloroform, shake and allow chloroform layer to separate. If indol is present a purplish red color is formed. Test is sensitive to 1 part in 1,000,000. Skatol produces a faint bluish color in dilutions of 1 part in 100,000.

g. *Beta-naphthaquinone reaction* (Herter 1905; Herter and Foster 1905, 1906; Bergheim 1917; Hawk 1918; Zoller 1920). To a dilute aqueous solution of indol (1:500,000) add 1 drop of a 2 per cent solution of B-naphthaquinone-sodium-mono-sulphonate. No re-



action occurs. Add a drop of a 10 per cent solution of potassium hydroxide and note the gradual development of a blue or blue-green color which fades to green if an excess of the alkali is added. Render the green or blue-green solution acid and note the appearance of a pink color. Heat facilitates the development of the color reaction. One part of indol in 1,000,000 parts of water may be detected by means of this test if carefully performed.

h. *Pine wood test* (Hawk 1918). Moisten a pine splinter with concentrated hydrochloric acid and insert it into the material under examination. The wood assumes a cherry-red color.

i. *Oxalic acid* (Morelli 1908). Oxalic acid either solid or in concentrated solution takes on a red color with indol or indol vapor. Blotting paper soaked with oxalic acid solution introduced into the incubator or hung over a culture dry or moist, reacts very sensitively for indol produced by the bacteria.

j. *Furfural* (Escallon and Sicre 1906). Extract culture with chloroform; drive off chloroform from the extract; take up residue in a few drops of alcohol, warm with 3 cc of the furfural reagent (glucose 1 gram and HCl 5 cc, warm to boiling, make up to 100 cc with water). Indol gives a reddish orange color.

k. *Glyoxylic acid* (Dakin 1906). To 1 cc of solution to be tested add 1 cc of a solution of calcium glyoxylate (containing 0.1 mg per cc) and 2 to 2.5 cc pure sulphuric acid. Note color at zone of contact and then slowly mix. Red color. Indol may be detected in a dilution of 1:200,000 and skatol 1:1,000,000.

l. *Pyruvic aldehyde* (Nelson 1916). To 5 cc of the solution to be tested add a small crystal of ferric sulphate and a few crystals of pyruvic aldehyde. A layer of concentrated sulphuric acid is then added and if indol is present a violet ring is formed. Indol may be detected in a dilution of 1:500,000.

### Skatol

a. *Dimethylaniline test* (Nelson 1916). To 5 cc of the solution to be tested add a few drops of dimethylaniline and shake vigorously. Add about 4 cc concentrated sulphuric acid to form a layer at the bottom. Violet ring is formed in dilutions of 1:1,000,000 or more. Color soluble in chloroform. Indol does not interfere.

b. *Para-dimethylaminobenzaldehyde reaction* (Hawk 1918). To

5 cc of the distillate or aqueous solution under examination add 1 cc of an acid solution of para-dimethylaminobenzaldehyde (made by dissolving 5 grams of para-dimethylaminobenzaldehyde in 100 cc of 10 per cent sulphuric acid) and heat the mixture to boiling. A purplish-blue coloration is produced which may be intensified through the addition of a few drops of concentrated hydrochloric acid. If the solution be cooled under running water it loses its purplish tinge of color and becomes a definite blue.

c. *Glyceric aldehyde* (Nelson 1916). To the solution to be tested add a drop or two of glyceric aldehyde and sulphuric acid. Skatol produces an intense red color, soluble in chloroform, while indol gives a yellow color insoluble in chloroform.

d. *Methyl alcohol* (Sasaki, date ?). To the solution to be tested add 3 or 4 drops of methyl alcohol and an equal volume of sulphuric acid. The acid must contain a trace of a ferric salt and the alcohol must be free from acetone. Reddish violet color produced with skatol. Indol does not interfere.

e. *Para-dimethylaminobenzaldehyde* (Blumenthal 1909; Steensma 1906). Test as for indol. Reaction not as delicate.

All of the methods given above except *i*, *j*, *k* and *l* for indol, and *c* for skatol, were tried experimentally; from them Ehrlich's test for indol (*f*) and either Herter's test (*b*) or the dimethylaniline test (*a*) for skatol, were selected as the most suitable for our use. Tests for indol, except *e*, *f* and *g*, and tests for skatol, except *a*, *b* and *c*, are not sensitive enough to be used with amounts of 1mmg indol or skatol.

The vanillin test for indol (*c*) is extremely delicate but frequently gives abnormal colors. Many substances other than indol give a similar color with vanillin. Experiments showed that HCl might be substituted for  $H_2SO_4$ ; the test was fully as sensitive and the charring effect of the concentrated  $H_2SO_4$  on organic substances was avoided. This test was frequently used as a confirmation test. A number of substituted vanillins were tried as color reagents and compared with vanillin. They proved to be less sensitive than vanillin and were discarded.

### B. Modification of the selected color tests

*Ehrlich test for indol* (*f*) being chosen as the one most suitable for our work on raw and canned salmon, experiments were under-

taken to increase its delicacy. The amount of indol in stale salmon is very small and the test to be used for its detection and estimation must be extremely delicate. The experiments were along the following lines:

The color of the glass of the test-tubes needs to be considered. It was frequently found that amounts of indol which should have given a definite color apparently gave little or none. On investigation it was found that some of the test tubes in use were made of glass which had a decided bluish-green color which served to mask partly or completely the faint pink color produced by small amounts of indol by either the Ehrlich or Vanillin test. Since we were attempting to record amounts of indol as small as 0.2-0.3 mmg the test tube was a big factor. Only thin test tubes of nearly colorless glass and as nearly as possible of uniform size were used in the experiments on raw and canned salmon.

P-dimethylaminobenzaldehyde dissolved in alcohol has a strong yellow color which tends to mask the pink color in faint indol tests. By reducing the amount of reagent this interference is partially eliminated. Half a cc of the Ehrlich reagent was the amount selected as the best for small amounts of indol (2.0 mmg or less).

Concentrated HCl partially destroys the yellow color of the p-dimethylaminobenzaldehyde reagent which interferes with the pink indol color. Since the 10 drops usually used have only a small effect, larger amounts were tried. A part of the yellow color was destroyed and the pink color became much more prominent. The indol color must be estimated at once however since it also is destroyed by the acid on standing. One cc was the amount selected as best for use with small amounts of indol.

The influence of heat on the color was observed. After several experiments with the indol test, it was found that the color developed much faster when the test tubes were heated than when left at room temperature. However the time of heating had to be short or the color was partially destroyed by the acid. Heating for 20 seconds appeared to be the most favorable treatment.

A modified Ehrlich method is given here. *Reagents:* (a) Para-dimethylaminobenzaldehyde, 2 grams in 100 cc of 95% alcohol; (b) HCl, 600 cc concentrated plus 200 cc of water; (c) Chloroform, U.S.P. *Method:* To 5 cc of the water test solution add 0.5 cc reagent *a* and 1 cc reagent *b*. Place in boiling water bath for about 20 seconds, shaking vigorously, then place in ice water about one-half minute and extract with 1 cc reagent *c*. Comparison is

made with standards prepared in exactly the same way. *Delicacy:* With pure water solutions of indol, 0.2 mmg may be easily detected in 5 cc, a dilution of 1:25,000,000.

*Herter's test for skatol (b)* is a very delicate one for both skatol and indol, but as in the Ehrlich test, the yellow color of the p-dimethylaminobenzaldehyde tends to obstruct the faint pink or blue produced by minute quantities of indol or skatol. Experiments indicated that 0.5 cc of the reagent to 5 cc of the solution to be tested gave better results than 1 cc. With this amount of reagent a distinct pink or blue could be obtained with 0.5 mmg indol or skatol in 5 cc of test solution, a dilution of 1:10,000,000. The distinction between indol and skatol is very marked even at this concentration, whereas the colors produced by the vanillin test on dilute solutions are very much alike. Substitution of 10 per cent HCl for 10 per cent H<sub>2</sub>SO<sub>4</sub> in making up the reagent was found advantageous, since the sulphuric acid tended to char organic substances in the test solutions obtained from fish, obscuring the results of the test.

A modified Herter's method is given here. *Reagents:* (a) Para-dimethylaminobenzaldehyde, 5 grams in 100 cc of 10% HCl; (b) Concentrated HCl; (c) Chloroform, U.S.P. *Method:* To 5 cc of the water test solution add 0.5 cc of reagent *a* and heat nearly to boiling. Add a few drops of reagent *b*, cool, add 1 cc reagent *c* and shake vigorously. Comparison is made with standards prepared in exactly the same way. *Delicacy:* Either indol or skatol could be easily detected, when present to the extent of 0.5 mmg in 5 cc water, a dilution of 1:10,000,000.

*The dimethylaniline test for skatol (a)*, as given in some unpublished work by the U.S. Bureau of Chemistry, prescribes sulphuric acid. Experiments showed that hydrochloric acid might be used instead and the charring effect of the sulphuric acid avoided. In this test heat should be used to bring out the color. Skatol gives a pink color; indol does not interfere unless present in very large amount.

A modified dimethylaniline method is given here. *Reagents:* (a) Dimethylaniline, C.P. and recently redistilled; (b) Concentrated HCl. *Method:* To 5 cc of the solution to be tested add 5 drops of reagent *a* and shake vigorously. Add 4 cc reagent *b* and heat in a water bath. *Delicacy:* With pure water solutions of skatol, 1.0 mmg may be easily detected in 5 cc, a dilution of 1:5,000,000.

### C. Distillation of indol from salmon

Indol and skatol, as well as some of the other products of decom-

position, are volatile with steam; and the question as to how completely they may be separated from such a material as fish by steam distillation at once arises. Zoller (1920a) has determined the percentage of recovery of indol from culture solutions of different pH concentrations, and concludes that a slightly alkaline solution (pH 9) gives the highest percentage. Bigelow and Cathcart (1921) give the pH value of canned salmon as 6.25, and the five species apparently do not differ appreciably. Furthermore, salmon in various stages of decomposition have been found to differ very little in hydrogen ion concentration. In order to ascertain the effect of reaction on the amount of indol recovered we made a number of distillations of water solutions of indol, using our regular method, with the exception that varying amounts of alkali or acid were added to the flask. The same amount of indol (12mmg) was used in each distillation, and 500 cc was distilled. The recovery in none of these cases was very satisfactory, but nearly twice as much was recovered from the alkaline solutions as from the acid.

Zoller also states that a higher percentage of recovery is attained when the volume of the liquid in the distilling flask is reduced as far as possible. We made a number of distillations, in some of which the liquid in the distilling flasks was allowed to increase, and in some the volume was much decreased. Twelve mmg indol were used and 500 cc distilled in each distillation. Reducing the volume increased the percentage of recovery.

The effect of adding NaOH to the fish in the distilling flask was next tried, but so much difficulty was experienced from frothing by the alkaline mixture, that this treatment was not considered feasible. Furthermore, Bigelow's work showed that canned salmon was nearly neutral, and correction of reaction was not as necessary as with more acid substances.

The percentage recovery of added indol from flasks containing fish formed the subject of the next experiments. Some fresh salmon was obtained from the market, skinned, boned and ground very fine, becoming thoroughly mixed in the process. A blank run on this salmon indicated that it was free from indol. Varying amounts of this fish with varying amounts of water and added indol were distilled and the percentage of recovery determined. The results showed that the recovery from fish was fully as good as that from water alone. They also showed that most of the indol which can be recovered from amounts of the magnitude used in these experiments is recovered in the first 500 cc of distillate.

To determine at what stage of the distillation most of the indol formed in decomposed salmon comes over, a series of experiments, using fish in various stages of decomposition, was carried out. These fish had been packed after being out of water from one to six days, and an idea of their condition can be obtained by consulting the data on chum salmon (6, F, below). Two hundred grams of fish, with 200 cc of water, was placed in the flask and distilled at a uniform rate. The distillate was collected in 100 cc amounts and the indol in each determined as carefully as possible. The liquid in the flask (water test solution), after the evaporation of ether, frequently required dilution, in order that the color produced might not be too intense.

The results of these experiments showed that when small amounts of indol are present a very large percentage of all that it is possible to distill from the fish or other material is obtained in the first 500 cc. With larger amounts the percentage grows smaller until, when using fish canned when 6 days old, the amount recovered in successive 100 cc portions was not strikingly less in distillate 7 than in distillate 1. The fact that the percentage obtained in the first 500 cc was rather small in the case of large amounts of indol was not particularly disturbing, since it was proposed to use the method as a measure of decomposition only in those cases in which the sense of smell was in doubt, in which cases only small amounts of indol, up to 6 mmg or less, were likely to be found. Therefore, in working with salmon it appears that it is satisfactory to distill one portion of 500 cc without the addition of alkali. An effort should be made to decrease the volume of liquid in the distilling flask to as small an amount as will still leave the contents in a fluid condition.

#### D. *Extraction of indol from the distillate*

The 500 cc distillate is transferred from the 600 cc beaker to a liter separatory funnel and extracted once with 100 cc of ether. Both ethyl ether and petroleum ether were used and the former finally selected as the most suitable, for several reasons. It was more easily obtained than petroleum ether of good grade. Frequently the latter could not be obtained from the local supply house and it was necessary to distill ordinary gasoline and use the low-boiling fraction. Frequently petroleum ether bought as low-boiling (below 60° C.) proved to contain 40% or more boiling above that temperature. Furthermore, some samples of petroleum ether contained impurities which interfered with color reactions, particularly with the vanillin

sulphuric acid reaction. Nearly every can of U.S.P. ethyl ether proved to be free from interfering substances and of course boiled at a constant low temperature. It was therefore used exclusively in the raw and canned salmon experiments.

When the distillate was violently shaken in the separatory funnel with the ethyl ether, a persistent emulsion usually resulted, from which only a part of the ether could be separated and also only a part of the indol. A quantity of concentrated HCl (10 cc) was therefore added to the funnel before shaking, which prevented the formation of an emulsion and gave a sharp separation of the ether and water. Care should be taken to use c.p. HCl, since there appears to be some substance in commercial HCl which interferes with the color test. Although only about 50 per cent of the ether used in the first extraction separates from the water, practically all of the indol which can be recovered is secured in the first extraction.

During decomposition other products than indol and skatol are formed, and since some of these may distill with steam and interfere with the color reactions for indol and skatol, the ether extracts of the distillate are washed with dilute NaOH (2.5%). Repeated experiments showed that washing with alkali alone rendered the water test solution alkaline and also interfered with the color reaction; however, if the ether was rewashed with dilute acid (10 cc concentrated c.p. HCl in 200 cc water) no interference with the color reaction was experienced. Repeated experiments showed that washed ether extracts gave clearer and slightly more intense color tests than exactly similar unwashed ether extracts.

#### E. *Evaporation of the ether extract*

After the ether extractions have been washed with alkali and acid they must be evaporated over a small amount of water (the test solution). This evaporation may be allowed to take place spontaneously; or be hastened by a current of air drawing away the ether vapor; or by heating, either on a hot plate or a water bath, or by immersion of the flask in hot water. All of these methods were tried in order to find which gave the least loss of indol. In each method the same quantity of ether (130 cc) received different amounts of indol in 15 cc of water and after evaporation the water was divided into three equal portions and the indol determined in each by a different method. The results indicated that some method of evaporation by heat was preferable to spontaneous evaporation, and among

the heating methods that of the steam bath seemed to be the best by a slight margin.

TABLE 7. *Loss of indol during the evaporation of the ether extract.*

Method	Indol added mmg.	Indol recovered in mmg.			
		Ehrlich's test	Herter's test	Vanillin test	Total
Spontaneous evaporation	12.	2.2	1.8	3.0	7.0
Immersion in hot water	12.	3.0	1.8	2.8	7.6
Hot plate	12.	3.0	3.0	3.8	9.8
Water bath and aspirator	12.	3.8	2.8	4.0	10.6

The temperature of the water test solution under the ether remains at about 40° C. until nearly all of the ether is gone, when it rapidly rises, and great care must be exercised at this point to take the flasks off the water bath while there is still a little ether left. The last traces of ether may be removed by rotating the warm flask and drawing air through it by an aspirator. All the ether must be removed before the test solution is divided for the color tests.

The amount of water used for the test solution varies but is usually 10 cc. This amount enables one to make check color tests on two 5 cc portions; or if the first 5 cc portion gives a color too intense for comparison with the standard colors, the second 5 cc may be diluted to any desired extent in order to reduce the amount of indol in 5 cc to about 3 or 4 mmg, which amounts give colors of maximum ease of comparison. Experiments were made which proved that such dilutions could be safely and accurately made.

#### F. *Color tests on the water test solution*

After the ether has been entirely removed from the flasks containing the test solutions, these are ready to be subdivided and the color tests made.

Usually the water test solutions consisted of 10 cc which was equally divided in two thin-walled, colorless, glass test tubes, one used for the test and one held in reserve. The tubes were placed in a rack in numerical order; and a series of standard tubes containing 0, 0.5, 1.0, 1.5, 2.0, 3.0, 4.0, 5.0 and 6.0 mmg indol in 5 cc of water arranged in another rack. A series of reagent burettes arranged on a revolving stand contained the following reagents: Water, standard indol solution, p-dimethylaminobenzaldehyde solution, hydrochloric acid, chloroform, and sometimes a modified Herter's reagent and a standard skatol solution. A boiling water



bath, having a basket of coarse wire screen inside to keep the test tubes from falling, and two beakers of ice water, completed the arrangements. Each tube received the reagents, was heated 20 seconds in the boiling water, and was plunged into ice water to cool, while a second tube received reagents and heating; after which the first tube was moved to the second beaker, and a third tube received reagents and heating. As soon as this tube was ready for the ice water, the first tube was cool enough to be extracted with 1 cc of chloroform, when it was placed in its proper place in the rack. By following this routine, each tube, in both the standard and unknown solutions, received exactly the same treatment. As soon as all the tubes had been treated they were compared with the standard tubes by holding in front of a piece of white paper and the color in the chloroform estimated as accurately as possible. The results were recorded in terms of mmg, on a basis of 100 grams of fish used.

Standard solutions of indol and skatol contained 4 mg per liter, and they were made up fresh about every day, for experiments proved that they lost strength very rapidly. Owing to the difficulty in weighing accurately so small an amount of indol as 4 mg, alcoholic solutions containing 80 mg in 100 cc were prepared. By pipetting 5 cc of the strong solution into a liter volumetric flask and filling to mark, a standard solution was easily and accurately prepared. Such concentrated solutions in alcohol, if tightly stoppered, will keep for months.

#### G. *The method as finally developed*

The substance to be examined is thoroughly mixed, by grinding in a meat grinder, if necessary, as in the case of raw salmon, and a sample weighing 200 grams transferred to a liter, round bottomed, long necked flask, using about 200 cc of water. A current of live steam is then passed through the mixture in the flask until 500 cc of distillate are collected. A gallon oil can, having a long glass safety tube placed in the opening on top and a rubber tube attached to the spout, makes a very satisfactory steam generator. The steam is passed through the fish by means of a glass tube reaching to the bottom of the flask (flask inclined at an angle of about 45°) and so bent near the end as to give a rotary motion to the contents as the steam issues from it. The flask is kept boiling hot by being placed in a boiling, saturated salt solution. The steam from the flask is received in a vertical worm condenser, the end of which projects below the surface of a small amount of water in the receiver (600 cc

beaker). The distillate is transferred to a liter separatory funnel, acidified with 10 cc c.p. concentrated HCl and extracted with 120 cc ethyl ether (U.S.P.) with repeated and vigorous shaking of the funnel. After the ether has separated, the ether layer is transferred to a 250 cc separatory funnel and washed first with 25 cc of NaOH solution (2.5%) and then with 25 cc dilute HCl (10 cc c.p. concentrated HCl plus 200 cc water). The first washing is to remove compounds which might interfere in the color tests, and the second to neutralize any alkali left in the ether. The ether is then placed in a small flask with 10 cc of distilled water and evaporated on a steam bath, taking great care that while the last of the ether is being driven off the water layer is not heated appreciably above the boiling point of ether, since the indol may be easily lost by volatilization at this stage. A 5 cc portion of the 10 cc water residue is now tested for indol, and 5 cc for skatol, by the modified tests before described (5, B).

## 6. EXPERIMENTAL WORK ON THE FIVE SPECIES OF SALMON IN DIFFERENT STAGES OF DECOMPOSITION

### A. General outline of the method employed

Having now developed a satisfactory method for the determination of indol and skatol in salmon, a comprehensive study of raw and of canned salmon was planned for the purpose of determining the significance of the presence of these decomposition products. This study was to cover the physical changes, the appearance and increase of indol or skatol, and a qualitative and quantitative investigation of the bacterial flora during progressive decomposition, together with such correlations among the physical, chemical and bacteriological changes as could be discovered.

These experiments will first be described in general, and any divergence from the general method will be given in the portion devoted to each species of salmon. In these portions the physical, chemical and bacteriological condition of each species of fish at the time of inspection are given in daily average tables showing the progressive nature of decomposition under each factor studied and in charts giving the results of the indol tests in both raw and canned salmon.

Dr. Carl R. Fellers, the bacteriologist of the laboratory, took charge of the bacteriological work, while Mr. Oscar E. Shostrom, assistant chemist, and I, were responsible for the physical and

chemical problems. Doctor Fellers has very kindly permitted me to include a part of the bacteriological results, in order to show the correlations between bacterial flora and indol and skatol content.

The salmon used in these experiments were obtained as they were taken from the traps, in order that there might be no question as to their exact age out of water. They were placed in boxes holding about 10 or 12 salmon each, and stored on the dock over the water, under cannery conditions as nearly as possible. In every case the traps were lifted early in the forenoon. The next morning and each succeeding morning (even periods of 24 hours each) one-sixth of the fish were brought from the dock to the laboratory by automobile. A maximum-minimum thermometer was placed with the fish stored on the dock, and each morning the range of temperature for the preceding 24 hours recorded. The fish taken each morning were selected without regard to their condition, some from the top and some from the bottom of the boxes. Immediately upon arrival at the laboratory, each fish received a designating letter, was hung upon a board which had been painted white and divided into six-inch (153-millimeter) squares with black lines, and was photographed with an ordinary kodak having a portrait lens attached. The raw salmon were then examined as follows<sup>7</sup>:

*Physical examination.* The salmon were laid in order on a large table, measured and weighed. Three of each species were again weighed after cleaning to show the percentage loss. The general appearance of the fish was then recorded as indicated below.

The skin, as the fish is taken from the water, is bright and free from slime, but it gradually grows dull and much slime appears. This slime forms an excellent medium for the growth of bacteria and helps to distribute them from fish to fish.

The scales adhere firmly at first but gradually grow looser.

The gills are bright red at first, gradually growing gray and finally greenish gray. Frequently the gills on one side of a fish were red while those on the other side were gray.

The eyes are bright, transparent and slightly bulging, when the fish is taken from the water. They gradually become bloodshot or gray, and less prominent, finally becoming sunken; in extreme cases only the socket may remain.

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<sup>7</sup>In the original typewritten thesis, deposited in the library of the University of Washington, a separate page is devoted to each of the 188 fish examined, giving all the physical, chemical and bacteriological data obtained, together with a photograph of the fish. Owing to the expense of printing, these data on individual fish have been omitted. However, the data have been averaged by days and are presented in tables, thus showing the decomposition changes from day to day.

The elasticity changes. Shortly after death the fish becomes rigid in *rigor mortis* and the flesh is firm. This rigidity is lost after a few hours but the flesh remains firm for some time. The flesh is elastic; where pressed in it immediately springs out again as soon as the pressure is removed. This response becomes slower and slower until finally impressions made with the thumb or finger remain.

Fly-blows and maggots are sought. Flies soon gather about a pile of fish; unless the heaps are well protected they receive masses of eggs. In about 24 hours these produce maggots, resulting in a very filthy condition.

*Bacteriological examination.* The scales were scraped from a small area near the back, close to the dorsal fin, and a hot iron was pressed against the skin until it was thoroughly seared over an area of about three square inches (58.5 sq. cm). With sterile scalpels and needles an incision was made to a depth of an inch (2.5 cm) or slightly less, and a piece of flesh weighing five or six grams placed in a weighed sterile bottle (250 cc) containing broken glass and 100 cc water. The bottle was weighed again and the exact weight of flesh taken determined. This process was repeated on the belly near the ventral fin. A small piece of the gills was also cut off with sterile scissors and placed in a bottle. The fish was then slit open and a piece of the intestine taken from just behind the stomach. (In the case of the king and pink salmon a piece of caecum was also taken and placed in a fifth bottle). The four bottles respectively containing weighed amounts of back flesh, belly flesh, gills and intestines were then shaken vigorously until the sharp pieces of glass had cut the tissues into very small pieces and the bacteria were as uniformly distributed in the liquid as possible. Dilutions were made, using sterile water, in order that the Petri dishes might not be thickly sown, and 1 cc of the diluted liquid placed in a Petri dish. The neutral dextrose agar used was composed of 5 g peptone, 5 g dextrose, 3 g beef extract, 15 g washed agar and 1,000 cc water. It was neutral to phenol red. The plates were incubated at 30° C. for 72 hours and the colonies counted. Other cultural characteristics of the organisms found in the back flesh were studied; among them, growth in anaerobic media (Van Ermengem 1912), and fermentative ability in dextrose and lactose media (Am. Pub. Health Assoc. 1920). Characteristic representative colonies were transferred from the agar plates to agar slants for preservation. Some of the anaerobic tubes were also preserved. The indol producing ability of many of these bacteria was later determined (7, A).

*Further physical examination.* The condition of the viscera was observed. As a rule no very striking changes took place for several days. Occasionally the viscera was found to be gray or bloody; after several days the viscera usually became soft, frequently broken, and in extreme cases partially liquified. In a few fish the belly walls were broken through so the viscera protruded. The reddening in belly walls is an index of condition. The normal color gradually gave place to a feverish red, which began at the gills and spread backward along the belly walls. The intensity of this abnormal color was greatest near the gills. This is a very characteristic sign of decomposition. It was found in practically every case after the fish had been standing 72 hours or more.

Gas gathers under the membranes. Usually on the fourth day, sometimes on the third, small bubbles were noticed under the membranes which line the belly cavity. By the fifth and sixth days these became very numerous and probably were scattered all through the flesh, producing the condition in canned fish spoken of as "honey-combing."

Loose ribs are an indication of condition. As the fish grew older the belly membranes grew weaker and the flesh became loosened from the bones in such a way that the ribs, during butchering and cleaning, frequently broke loose from the belly walls.

The odor of the gills, viscera, walls of the belly cavity, and flesh in the back, were carefully recorded. The descriptive terms used were: good, lack of odor, stale, taint and putrid; both stale and taint were frequently divided into three degrees, for example, slightly stale, stale, strongly stale. The flesh of all the fish 24 hours old had a good normal fish odor. Frequently the flesh of fish 48 hours old did not possess this characteristic odor nor did it have any odor of decomposition. In such cases we reported this condition as "lack of odor." Stale fish had abnormal odors, with a slight suggestion of decomposition while tainted fish had an unmistakable odor of decomposition; when this was extreme, the fish were spoken of as putrid.

*Chemical examination.* The amount of indol in the gills, viscera and flesh was determined. The gills, together with the bony structures to which they are attached, were ground in a meat grinder and thoroughly mixed. Under the term "viscera" we placed everything within the belly cavity, including eggs or milt. This was ground and mixed. Whenever the ground gills or viscera amounted to 200 grams, this amount was taken for distillation. When there was

less than 200 g, as large a sample as possible was taken and the weight recorded in order that the indol might be calculated to the uniform basis of 100 g. After the dressed fish was thoroughly washed, portions of the flesh were distilled for indol. The portions selected varied with the different species and are described in the part devoted to each species. These determinations were made according to the method given in 5, G of this paper.

*Canning.* The remainder of the dressed and cleaned fish was cut transversely into sections of suitable length for half pound (227g) cans. In the case of large fish, some of these sections were big enough to fill two cans; in such cases the section was cut into two nearly equal pieces, and the can receiving the piece without the backbone was marked with a star. The cans were placed in order; and as soon as the covers were clinched on, were marked in such a manner as to identify the species, the individual fish, and the particular section of that fish. For example, the cans obtained from the coho salmon "A" were marked as follows:

CA1	CA2	CA3	CA4	CA5	CA6	CA7	CA8	CA9
	CA2*	CA3*	CA4*		CA6*	CA7*		

In every case from 8 to  $8\frac{1}{4}$  oz. (227-234 g) of fish were placed in each can with about  $\frac{1}{8}$  oz. (3.5g) of salt. All of the cans, except those containing the king salmon, were exhausted before cooking. For this purpose the covers were clinched on rather loosely and the cans placed in a pressure cooker with the steam issuing freely from the petcock. They remained in the live steam for 12 minutes and were then tightly closed with a hand seamer. All of the cans were cooked at 10 pounds (4.54 kg) pressure ( $240^{\circ}$  F. or  $115.5^{\circ}$  C.) for 80 minutes, then removed and allowed to cool on the cement floor. A few days after all of the fish of one species were canned, certain cans from each fish were carefully examined according to the method outlined in 2. The cans selected and the reason for their selection are considered in the parts devoted to the several species.

### B. *Experimental work on king salmon*

Eighteen king salmon were obtained as they were taken from a trap in the San Juan Islands at 10 a. m., July 30. They were immediately placed in two large fish boxes, covered, and brought on a fish boat to the dock of the San Juan Fish Company at Seattle, where the boxes were stored near the sea end of the dock. The maximum and minimum temperatures in the 7 readings in the fish boxes during

the 6 days of storage were, in centigrade degrees, 21.1 and 15.6, 23.3 and 15.3, 21.1 and 16.1, 19.4 and 15, 19.6 and 15, 19.4 and 15, 20.9 and 14.4; (in Fahrenheit degrees 70 and 60, 74 and 59.5, 70 and 61, 67 and 59, 67.5 and 59, 67 and 59, 69.5 and 58).

Three fish were brought to the laboratory each morning. Indol determinations were made on the gills, viscera and flesh. With a view to obtaining a sample which should represent the whole fish, pieces of flesh, each weighing about 250 grams, were taken from the two ends of the dressed and cleaned fish. These were ground together, mixed, and two portions of 200 g each distilled for indol. The results indicate that an unfortunate selection of flesh was made. The first cut of each fish is likely to contain more indol than any other cut, due to the rapid bacterial invasion from the gills. The last cut also contains more than the average for the fish as a whole. Therefore, since these cuts were selected for the determination of indol in the raw fish, the results were bound to be much higher than those obtained in the cooked salmon using cuts less heavily invaded by bacteria. The indol was determined in three cans from each fish representing the third, sixth and next to the last cuts. The first and last cuts had been used raw, and the second cut (canned) was saved for possible use in a series of food analyses to be made during the winter. The three cans selected gave an idea of the condition of the fish at points near the ventral fins, near the end of the body cavity, and near the tail. (See table 8 and Fig. 2).

### C. *Experimental work on pink salmon*

Thirty-six pink salmon taken from a trap in the San Juan Islands about 9 a. m., August 17, were placed in boxes, covered, and brought on a fish boat to the dock of the San Juan Fish Company at Seattle, where the boxes were stored near the sea end of the dock. The maximum and minimum temperatures in the fish boxes during the six days of storage were, in degrees centigrade, 16.1 and 11.7, 16.7 and 12.2, 18 and 13.3, 19.4 and 13.6, 18 and 14.4, 18.9 and 14.4; (in degrees Fahrenheit, 61 and 53, 62 and 54, 64.5 and 56, 67 and 56.5, 64.5 and 58, 66 and 58). (See also table 9 and Fig. 3).

Six fish were brought to the laboratory each morning. Flesh for the indol test consisted of a portion from each end of the fish together with a portion, equal to the two other portions combined, consisting of an entire section of the fish in the region of the dorsal fin. These three portions, weighing altogether about 250 grams, were ground together and mixed. Owing to the small size of the fish, only

TABLE 8. *Average daily decomposition changes in king salmon*

Days	1	2	3	4	5	6
Weight in pounds	14.2	15.8	15.2	12.9	12.3	12.8
Length in inches	31.5	32.8	31.6	31.0	30.0	30.0
Skin	Bright	Bright	Sl. dull	Dull	Dull	Very dull
Scales, adherence	Firm	Firm	Sl. loose	Sl. loose	Loose	Dried on
Eyes	Bright	Sl. sunken	Sunken	Sunken	Sunken-gone	Gone
Gills	Red	Sl. gray	Gray	Sl. gray	Gray, sept-d	Gray, sept'd
Elasticity	Immediate	Sl. slow	Slow	Imp. remains	Entire, soft	Very soft
Viscera	Entire	Entire	Entire	Entire, soft	Marked	Partly gone
Reddening, flesh	None	None	Slight	Slight	Marked	Marked
Gas, membranes	None	None	None	Some	Marked	Marked
Ribs broken loose	No	No	Slightly	Badly	Badly	Badly
Odor, gills	Sl. stale	Sl. taint	Taint	Putrid	Putrid	Putrid
Odor, viscera	Good	Stale	Taint	Taint	Taint	Putrid
Odor, belly walls	Good	Sl. stale	Taint	Putrid	Putrid	Putrid
Odor, back flesh	Good	Sl. stale	Stale	Putrid	Putrid	Putrid
Indol, gills	23.8	8.8	147.0	506.0	1033.0	1500.0
Indol, viscera	3.6	4.7	14.2	10.8	20.3	220.0
Indol, flesh	0.5	1.16	7.83	29.15	93.3	178.8
Bacteria, gills	9,000	22,900	83,000	385,000	205,000	4,290,000
Bacteria, viscera	900	590	225	165	16,000	103,500
Bacteria, belly flesh	0	1,800	23,600	269,500	2,516,000	206,000
Bacteria, back flesh	0	2,000	40,200	17,300	370,000	115,000

Examination of the canned salmon		1	2	3	4	5	6
Liquid, turbidity	Normal	Normal	Normal	Sl. turbid	Sl. turbid	Turbid	Turbid
Odor	Good	Good	Stale	Sl. taint	Taint	St. taint	St. taint
Texture	Firm	Firm	Sl. soft	Sl. soft	Soft	Soft	Soft
Color	Good	Average	Average	Abnormal	Abnormal	Abnormal	Abnormal
Reddening, flesh	None	None	V. slight	Slight	Marked	Marked	Marked
"Honeycombing"	None	None	Slight	Marked	Marked	Marked	Marked
Biting taste	None	None	Slight	Marked	Marked	Marked	Marked
Ribs broken loose	No	No	No	Slightly	Badly	Badly	Badly
Indol	0.39	0.92	2.08	16.02	35.1	32.05	32.05
Bact. examination	8 sterile	9 sterile	8 sterile	7 sterile	9 sterile	9 sterile	9 (all) sterile



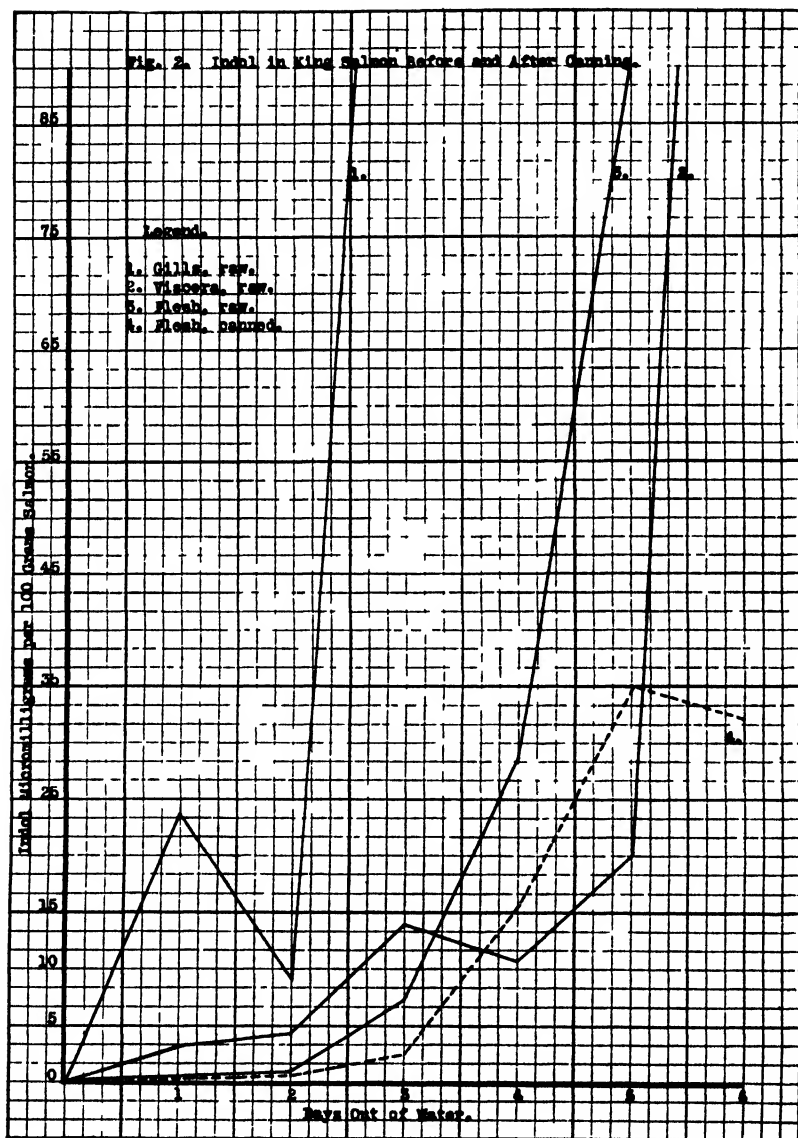


Fig. 2. Indol in king salmon before and after canning.

TABLE 9. *Average daily decomposition changes in pink salmon*

Days	1	2	3	4	5	6
Weight in pounds	4.1	3.5	3.5	4.0	4.3	3.4
Length in inches	21.5	20.9	20.7	22.0	22.6	20.7
Skin	Bright	Bright	V. sl. dull	Sl. dull	Sl. dull	Dull
Scales, adherence	Firm	Sl. loose	Loose	Sl. loose	Sl. loose	Sl. loose
Eyes	Bright	Sl. bloody	Bloody	Sunken	Sunken	Gone
Gills	Red	Sl. gray	Sl. gray	Gray	Gray	Gray, sept'd
Elasticity	Immediate	Sl. slow	Slow	Very slow	Imp. remains	Soft
Viscera	Entire	Entire	Entire	Entire, soft	Sl. broken	Broken
Reddening, flesh	None	None	Slight	Slight	Marked	Marked
Gas, membranes	None	None	None	None	Some	Marked
Ribs broken loose	No	No	Slightly	Badly	Badly	Badly
Odor, gills	Sl. stale	Sl. stale	Sl. stale	Taint	Putrid	Putrid
Odor, viscera	Good	Good	Sl. stale	Sl. taint	Sl. taint	Taint
Odor, belly walls	Good	Good	V. sl. stale	Sl. taint	St. taint.	Taint
Odor, back flesh	Good	Good	Good	Stale	Taint	Taint
Indol, gills	0.56	1.8	5.5	378.0	423.0	918.0
Indol, viscera	0.15	0.17	0.23	2.7	1.4	34.0
Indol, flesh	0.1	0.18	0.25	2.65	23.6	90.0
Bacteria, gills	30,500	49,500	1,314,500	2,157,500	70,958,000	37,891,000
Bacteria, viscera	226	2,130	45,500	65,000	2,581,000	970,000
Bacteria, belly flesh	1,450	15,500	44,300	21,500	2,490,000	353,000
Bacteria, back flesh	85	17,100	30,400	8,500	448,000	32,800
Examination of the canned salmon						
Liquid, turbidity	Normal	Normal	Sl. turbid	Sl. turbid	Turbid	Turbid
Odor	Good	Good	Stale	Sl. taint	Taint	Putrid
Texture	Firm	Sl. soft	Sl. soft	Soft	Soft	Soft
Color	Average	Average	Average	Abnormal	Abnormal	Abnormal
Reddening, flesh	None	None	Slight	Marked	Marked	Marked
"Honeycombing"	None	None	Slight	Marked	Marked	Marked
Biting taste	None	None	Slight	Marked	Marked	Marked
Ribs broken loose	No	No	Yes	Badly	Badly	Badly
Indol	0.35	0.33	0.53	1.92	7.77	15.66
Bact. examination	5 sterile	6 sterile	6 sterile	5 sterile	6 (all) sterile	3 sterile

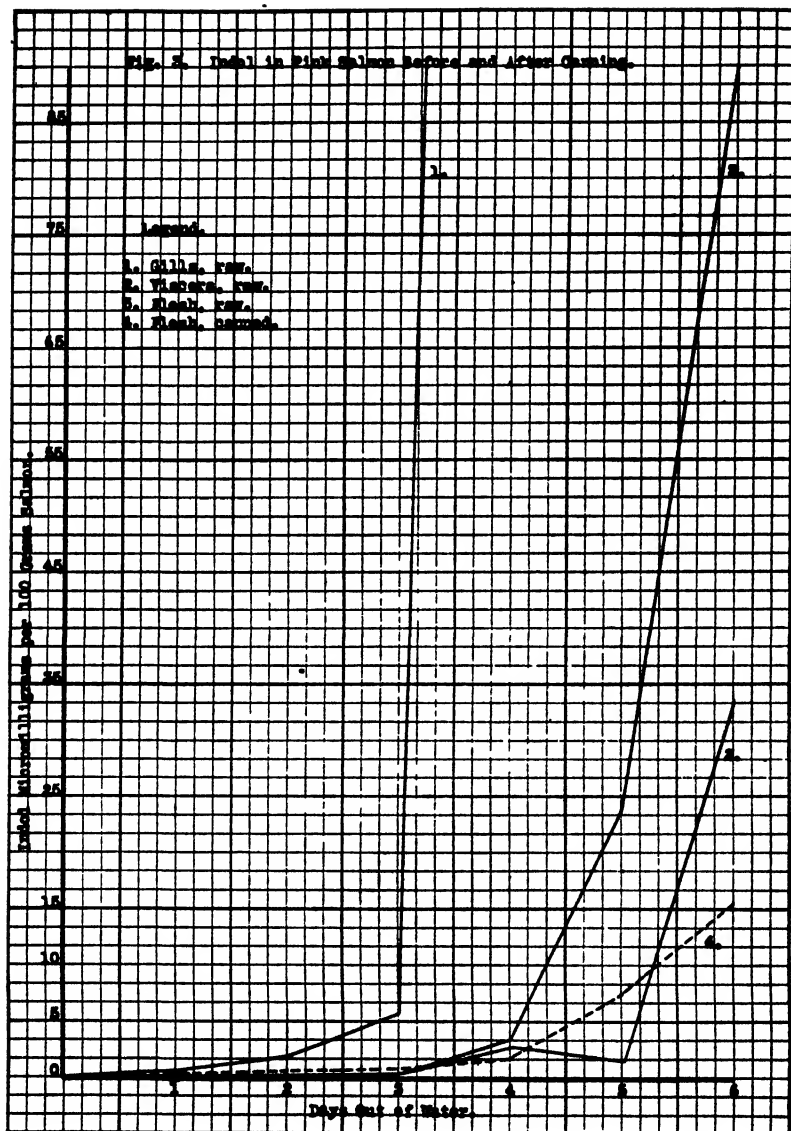


Fig. 3. Indol in pink salmon before and after canning.

one indol determination was made on the flesh. The results again indicated that the portions of the flesh were not wisely selected.

#### D. *Experimental work on sockeye salmon*

Thirty sockeye salmon were obtained as they were taken from a trap in the San Juan Islands about 9 a.m., September 3. They were immediately placed in boxes on the deck of the fish boat, covered, and brought to Seattle. Upon arrival early in the morning of September 4, five were taken at once to the laboratory, and the rest stored on the dock. The maximum and minimum temperatures in the fish boxes during the 6 days of storage were, in centigrade degrees, 16.7 and 12.2, 16.7 and 10, 15.6 and 13.3, 17 and 11.7, 16.7 and 11.1, 16.7 and 11.7; (in Fahrenheit degrees, 62 and 54, 62 and 50, 60 and 56, 62.5 and 53, 62 and 52, 62 and 53). (See table 10 and Fig. 4).

Five sockeyes were brought to the laboratory each morning. Flesh for the indol determination was selected in such a way as to show whether the cooking of the canned fish increased or diminished the amount of indol present. The first transverse section of the fish (called the first cut) consisting of about one pound (454 g) was divided as equally as possible into two parts, in one of which the indol was determined at once, and in the other after canning. A section of similar weight, cut from the fish just in front of the dorsal fin (usually the third or fourth cut) was treated in an exactly similar manner. The results gave a much closer agreement between the raw and cooked salmon than was obtained with the king and the pink salmon.

#### E. *Experimental work on coho salmon*

Twenty four coho salmon were obtained as they were taken from a trap in the San Juan Islands about 9 a.m., September 3. They were immediately placed in boxes on the deck of the fish boat, covered, and brought to Seattle. Upon arrival, early in the morning of September 4, four were taken at once to the laboratory, and the rest stored on the dock. The maximum and minimum temperatures in the fish boxes during the 6 days of storage were, in centigrade degrees, 16.7 and 12.2, 16.7 and 10, 15.6 and 13.3, 17 and 11.7, 17 and 11.7, 16.7 and 11.1, 16.7 and 11.7; (in Fahrenheit degrees, 62 and 54, 62 and 50, 60 and 56, 62.5 and 53, 62 and 52, 62 and 53).

Four coho salmon were brought to the laboratory each morning. Flesh for the indol determination was selected as in the case of the sockeye salmon. The results gave a much closer agreement between the raw and the cooked salmon than was obtained with the king and the pink salmon. (See table 11 and Fig. 5).

TABLE 10. *Average daily decomposition changes in sockeye salmon*

Days	1	2	3	4	5	6
Weight in pounds	6.35	5.9	6.25	5.35	5.55	6.2
Length in inches	25.0	23.9	24.8	22.8	23.5	24.8
Skin	Bright	Bright	Sl. dull	Dull	Dull	Very dull
Scales, adherence	Firm	Sl. loose	Loose	Loose	Loose	Very loose
Eyes	Bright	Sl. bloody	Bloody	Sunken, gray	Sunken, gone	Sunken, gone
Gills	Bright red	Sl. gray	Sl. gray	Gray	Gray	Gray, sept'd
Elasticity	Immediate	Sl. slow	Slow	Imp. remains	Imp. remains	Soft
Viscera	Entire	Entire	Entire	Entire	Entire, gray	Sl. broken
Reddening, flesh	No	No	Slight	Slight	Marked	Marked
Gas, membranes	No	No	No	Slight	Marked	Marked
Ribs broken loose	No	No	Slightly	Slightly	Badly	Badly
Odor, gills	Good	Stale	Taint	Taint	Taint	Putrid
Odor, viscera	Good	Good	Sl. stale	Sl. stale	Stale	St. stale
Odor, belly walls	Good	Good	Stale	St. stale	Sl. taint	Taint
Odor, back flesh	Good	Good	Sl. stale	Stale	St. stale	Sl. taint
Indol, gills	1.6	23.1	156.5	139.0	266.0	591.0
Indol, viscera	0.16	0.1	0.54	1.8	8.5	14.2
Indol, first cut	0.1	0.36	2.4	9.7	33.0	38.2
Indol, dorsal cut	0.0	0.24	1.4	4.2	17.3	25.2
Bacteria, gills	172,000	74,000	7,500,000	4,960,000	25,165,000	6,130,000
Bacteria, viscera	2,700	670	491,000	18,900	278,000	120,900
Bacteria, belly flesh	8	410	520	7,660	210,000	1,650,000
Bacteria, back flesh	6	29	89	6,790	17,100	133,200
Examination of the canned salmon						
Liquid, turbidity	Normal	Normal	Sl. turbid	Sl. turbid	Turbid	Turbid
Odor	Good	Good	Stale	St. stale	Taint	Taint
Texture	Firm	V. sl. soft	Sl. soft	Sl. soft	Soft	Soft
Color	Good	Good	Average	Abnormal	Abnormal	Abnormal
Reddening, flesh	None	None	V. slight	Sl. marked	Marked	Marked
"Honeycombing"	None	None	V. slight	Marked	Marked	Marked
Biting taste	None	None	V. slight	Marked	Marked	Marked
Ribs broken loose	No	No	No	Slightly	Badly	Badly
Indol	0.2	1.9	2.45	5.05	19.2	28.3
Bact. examination	Sterile	Sterile	Sterile	Sterile	Sterile	Sterile

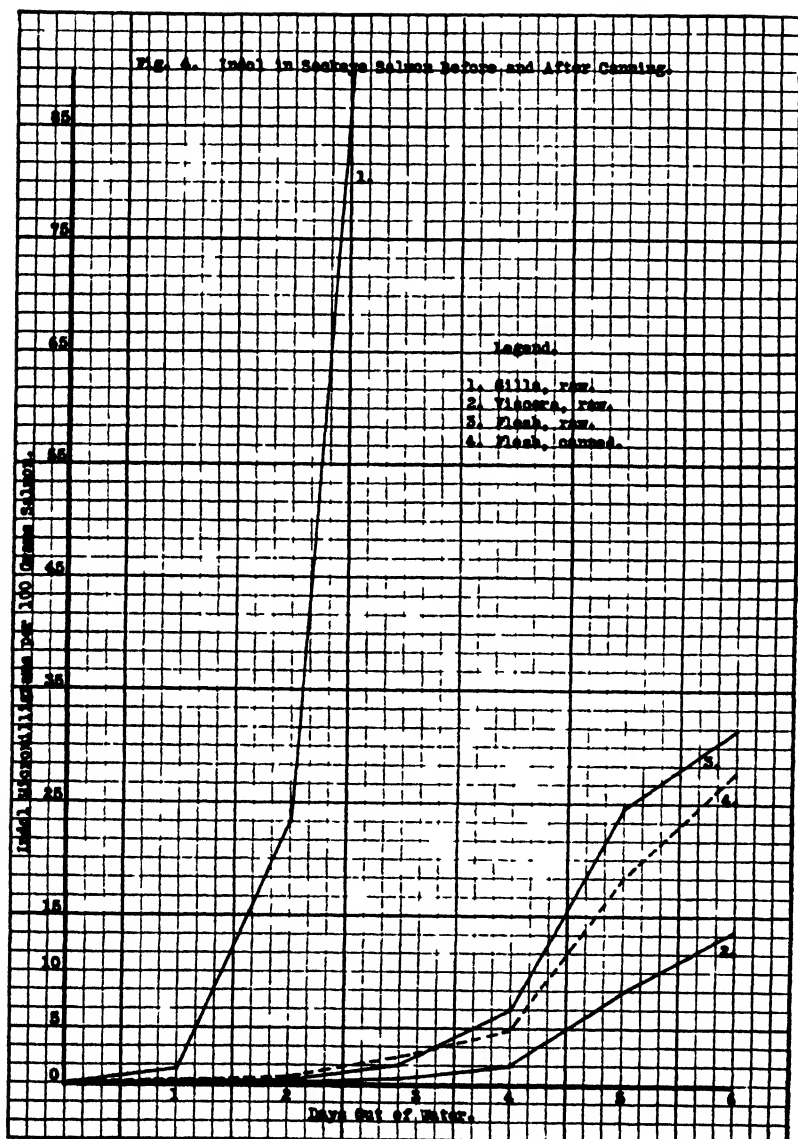


Fig. 4. Indol in sockeye salmon before and after canning.

TABLE 11. *Average daily decomposition changes in coho salmon*

Days	1	2	3	4	5	6
Weight in pounds	11.5	9.4				12.0
Length in inches	27.5	26.2	8.8	9.0	9.5	28.5
Skin	Bright	Bright	Sl. dull	Dull	Dull	Dull
Scales, adherence	Firm	Sl. loose	Sl. loose	Loose	Loose	Very loose
Eyes	Bright	Sl. bloody	Sunken, gray	Sunken, gray	Sunken, gone	Sunken, gone
Gills	Bright	Sl. gray	Sl. gray	Gray, sept'd	Gray, sept'd	Gray, sept'd
Elasticity	Immediate	Sl. slow	Slow	Imp. remains	Imp. remains	Very soft
Viscera	Entire	Entire	Entire	Entire	Broken, gray	Sl. broken
Reddening, flesh	None	None	Sl. light	Slight	Marked	Marked
Gas, membranes	None	None	No	Yes	Marked	Marked
Ribs broken loose	No	No	No	Sl. to badly	Badly	Badly
Odor, gills	Good	Sl. stale	Slightly	Taint	Sl. taint	Sl. taint
Odor, viscera	Good	Good	Sl. stale	Stale	Sl. taint	Sl. taint
Odor, belly walls	Good	Sl. stale	Stale	St. stale	Taint	Taint
Odor, back flesh	Good	Good	Sl. stale	Stale	St. stale	Sl. taint
Indol, gills	0.3	16.5	11.5	103.0	263.0	196.0
Indol, viscera	0.1	0.1	0.7	1.0	0.6	2.1
Indol, first cut	0.1	0.25	1.3	6.2	15.0	31.6
Indol, dorsal cut	0.0	0.1	0.8	3.8	15.7	14.5
Bacteria, gills	1,840	30,000	636,700	412,500	3,900,000	597,500
Bacteria, viscera	237	49	11,700	15,900	436,000	1,100
Bacteria, belly flesh	20	6,570	460	400	67,500	19,300
Bacteria, back flesh	0	3,000	1,380	190	86,200	24,500
Examination of the canned salmon						
Liquid, turbidity	Normal	Normal	Sl. turbid	Turbid	Turbid	Turbid
Odor	Good	Good	Stale	Taint	Taint	Taint
Texture	Firm	Firm	Sl. soft	Soft	Soft	Soft
Color	Good	Good	Good	Abnormal	Abnormal	Abnormal
Reddening, flesh	None	None	Slight	Marked	Marked	Marked
"Honeycombing"	None	0.4	Slight	Marked	Marked	Marked
Biting taste	None	None	Slight	Marked	Marked	Marked
Ribs broken loose	None	None	No	Yes	Yes	Yes
Indol	0.22	No	2.1	5.9	16.4	20.1
Bact. examination	8 sterile	8 sterile	8 sterile	6 sterile	8 sterile	8 (all) sterile

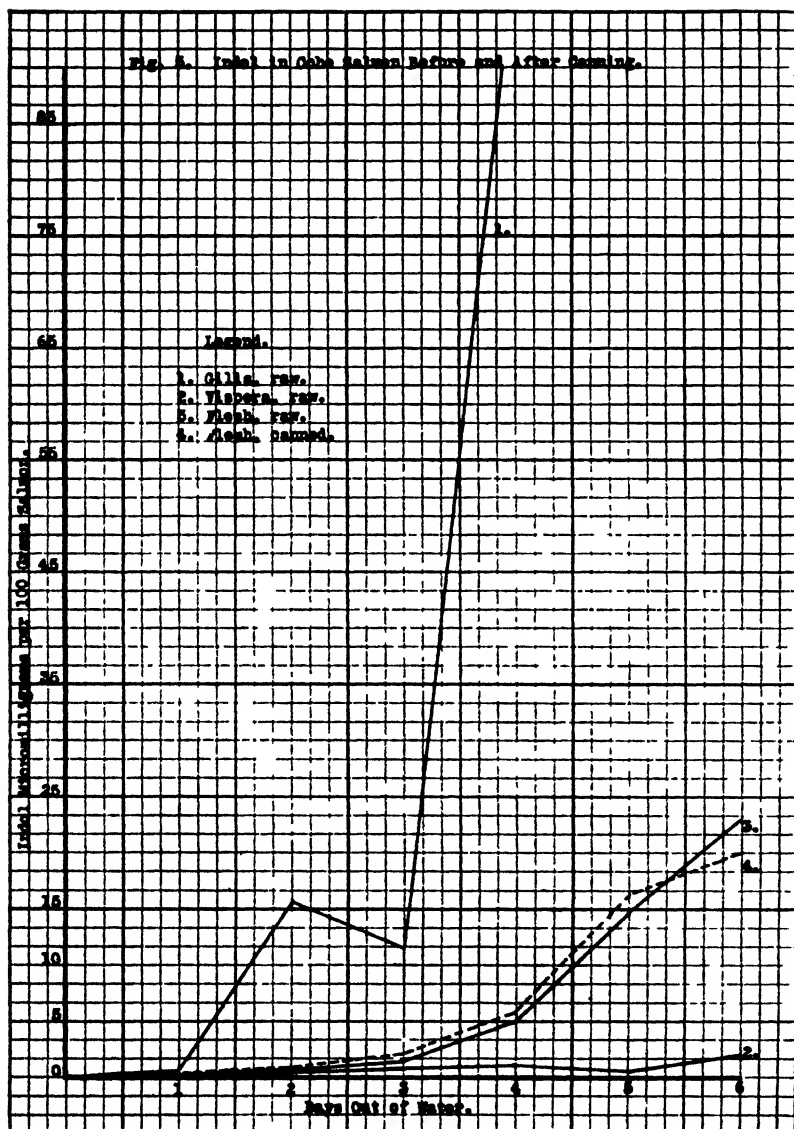


Fig. 5. Indol in coho salmon before and after canning.



### F. *Experimental work on chum salmon*

Thirty chum salmon were obtained from a trap at Meadow Point, near Seattle, about 8 a.m., October 22. They were brought to Seattle on a scow and unloaded at the dock about 10 a.m. All of the fish were taken at once to the laboratory and stored in a box having several shelves so that there might not be too much pressure on any of the fish. For two days the box was kept in the laboratory near an open window and was then moved outside. The maximum and minimum temperatures in the box during the 6 days of storage were, in centigrade degrees, 20.6 and 15, 21.7 and 16.7, 22.2 and 11.1, 14.4 and 11.1, 17.8 and 11.1, 13.3 and 10.6; (in Fahrenheit degrees, 69 and 59, 71 and 62, 72 and 52, 58 and 52, 64 and 52, 56 and 51.)

Five fish were used each day. Flesh for the indol determination was selected as in the case of the sockeye salmon. The results were somewhat higher in the fish out of water 48 hours than the results obtained from any of the other species, probably due to the higher storage temperature. (See table 12 and Fig. 6).

*Indol in raw salmon* at different stages of decomposition was quantitatively determined in 138 fish. Two determinations were made on each fish, with the exception of the pink salmon, on which but one was made. In all, 229 determinations were made. Although the results have already been given they are rearranged here to bring out the correlation between indol content and odor; and for comparison with the results obtained with the same salmon when canned (table 14) as well as those obtained with commercial cans of salmon (table 15). The odor on which table 13 was based was the odor of the belly cavity.

As the odor of decomposition increased in the belly cavity, the amount of indol in the flesh also increased. The percentage of determinations having 1.5 mmg indol or more per 100 g of salmon increased in proportion to the odor of decomposition. The agreement between the results given here and those given in table 14 is very good. The terms used here to designate odor have been defined in 2. Although it is recognized that stale fish is of inferior quality, it is usually considered as not unfit for food. In this and other tables, therefore, those fish or cans of fish classed as stale have been designated as "passed by odor as fit for food," while tainted fish or cans of fish have been designated as "not passed by odor."

*Indol in experimental packs* of canned salmon was quantitatively determined in 269 cans of the five species. The results have already

TABLE 12. *Average daily decomposition changes in chum salmon*

Days	1	2	3	4	5	6
Weight in pounds	11.5	12.2	10.9	9.1	10.1	10.8
Length in inches	29.4	30.0	29.1	27.8	28.3	29.7
Skin	Bright	Bright	Sl. dull	Dull	Dull	Very dull
Scales, adherence	Firm	Sl. loose	Sl. loose	Loose	Loose	Very loose
Eyes	Bright	Sl. bloody	Sunken, gray	Sunken, gray	Sunken, gone	Sunken, gone
Gills	Bright red	Sl. gray	Gray	Gray	Gray-green	Gray-green
Elasticity	Immediate	Quickly	Slowly	Slowly	Very slow	Imp. remains
Viscera	Entire	Entire	Sl. gray	Sl. broken	Gray	Sl. broken
Reddening, flesh	None	None	Slight	Marked	Marked	Marked
Gas, membranes	None	None	Slight	Marked	Marked	Marked
Ribs broken loose	No	No	Slightly	Slightly	Sl. to badly	Badly
Odor, gills	Good	St. stale	Taint	Putrid	Putrid	Putrid
Odor, viscera	Good	Good	Stale	Taint	Taint	St. taint
Odor, belly walls	Good	Sl. stale	Stale	Sl. taint	Taint	St. taint
Odor, back flesh	Good	Sl. stale	Stale	St. stale	Taint	St. taint
Indol, gills	0.8	15.9	66.4	197.0	938.0	866.0
Indol, viscera	0.4	1.3	3.5	10.2	44.0	126.0
Indol, first cut	0.26	1.4	8.0	17.7	58.0	91.0
Indol, dorsal cut	0.1	0.5	3.8	6.9	19.7	42.0
Bacteria, gills	180,800	3,819,000	85,960,000	41,000,000	616,000,000	1,123,000,000
Bacteria, viscera	1,490	33,720	167,000	929,000	1,153,000	8,275,000
Bacteria, belly flesh	16	1,570	57,500	116,100	1,944,000	2,538,000
Bacteria, back flesh	2	296	29,500	32,500	2,512,000	1,502,000
Examination of the canned salmon						
Liquid, turbidity	Normal	Normal	Sl. turbid	Turbid	Turbid	Turbid
Odor	Good	V. sl. stale	St. stale	Taint	St. taint	Putrid
Texture	Firm	Firm	Sl. soft	Soft	Soft	Soft
Color	Good	Good	Average	Abnormal	Abnormal	Abnormal
Reddening, flesh	None	Very slight	Slight	Marked	Marked	Marked
"Honeycombing"	None	None	Slight	Marked	Marked	Marked
Biting taste	None	None	Slight	Marked	Marked	Marked
Ribs broken loose	No	No	V. slightly	Slightly	Badly	Badly
Indol	0.25	1.8	9.6	24.6	51.8	84.4
Bact. examination	9 sterile	9 sterile	9 sterile	9 sterile	10 sterile	10 (all) sterile

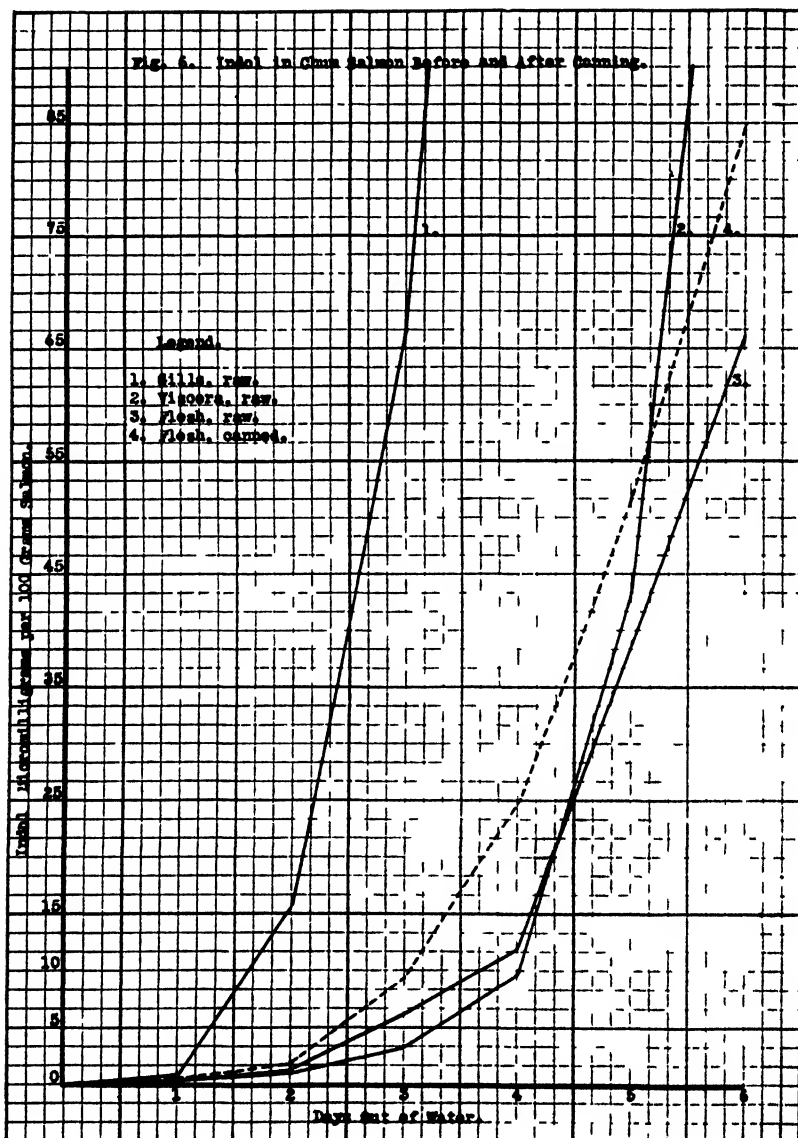


Fig. 6. Indol in chum salmon before and after canning.

TABLE 13. *Correlation between indol and odor in raw salmon.*

Indol mmg per 100 g salmon	Number of cuts classed by odor as					Total
	Good	Slightly stale	Stale	Strongly stale	Tainted or putrid	
0.1—0.5	58	10	3	0	0	71
0.6—1.0	4	10	4	0	0	18
1.1—1.4	0	1	2	0	0	3
1.5—	0	10	21	12	94	137
Total	62	31	30	12	94	229
1.5—	0.0%	32.2%	70.%	100.%	100.%	59.8%

	Reported as good.	Reported as stale.
0.1—0.5	68	3
0.6—1.0	14	4
1.1—1.4	1	2
1.5—	10	33
Total	93	42
1.5—	10.7%	78.5%

	Passed by odor as fit for food.	Not passed by odor.
0.0—0.5	71	0
0.6—1.0	18	0
1.1—1.4	3	0
1.5—	43	94
Total	135	94
1.5—	31.8%	100.%

been given in the previous pages of this section but are rearranged here in order to bring out the correlation between indol content and odor. Furthermore, comparison with the raw salmon used, and with commercial packs of salmon, can be more easily made.

The results show an increasing percentage of cans containing 1.5 mmg (or more) per 100 g of salmon, with an increase in the odor of decomposition. A few of the cans classed as good (3.9%) contained as much as 1.5 mmg while practically all of those classed as strongly stale or tainted contained this amount or more. The percentage of cans containing indol to the extent of 1.5 mmg or more is much higher than in the case of commercial cans of salmon (table 15). The agreement between the raw salmon (table 13) and the experimental cans of salmon prepared from them (table 14) is very good. Why the commercial cans contained less indol is not known. It may be that the bacterial flora was different. Pugsley (date?) carried on a decomposition experiment similar to the one described in this section, using chum salmon which had been in cold storage for three months,

TABLE 14. *Correlation between indol and odor in experimental cans of salmon.*

Indol mmg per 100 g salmon	Number of cans classed by odor as—					Total
	Good	Slightly stale	Stale	Strongly stale	Tainted or putrid	
0.0—0.5	46	4	2	1	0	53
0.6—1.0	24	6	8	0	1	39
1.1—1.4	3	2	3	0	1	9
1.5—	3	7	22	24	112	168
Total	76	19	35	25	114	269
1.5—	3.9%	36.8%	62.8%	96.6%	98.7%	62.4%

	Reported as good.	Reported as stale.
0.0—0.5	50	3
0.6—1.0	30	8
1.1—1.4	5	3
1.5—	10	46
Total	95	60
1.5—	10.5%	65.9%

	Passed by odor as fit for food.	Not passed by odor.
0.0—0.5	53	0
0.6—1.0	38	1
1.1—1.4	8	1
1.5—	56	112
Total	155	114
1.5—	36.1%	98.7%

and some which had not been in cold storage at all. The results were entirely different. As stated in 7, A, apparently all of the indol forming bacteria had been killed during cold storage, and both the raw salmon and the canned salmon prepared from them contained almost no indol even after five or six days' storage at room temperature; whereas the raw salmon which had not been in cold storage, and the canned salmon prepared from them, contained large amounts of indol after the third day. This example shows what a big variation in decomposition products may result from different bacterial floras.

*Indol in commercially canned salmon* was quantitatively determined in 544 cans during a period of ten months. These cans were drawn from 168 separate parcels of salmon, many of which were of rather poor quality. For this reason the proportion of stale and tainted cans is very much higher than is found in the average parcel of canned salmon. In all 1,897 cans were opened for examination and 544 tested for indol. In some of the samples the first 12 cans opened

were used for the indol test without regard to their condition, while in many samples only those which were classed as stale or tainted were used. This is an additional reason why the proportion of stale and tainted cans is so large in table 15.

TABLE 15. *Correlation between indol and odor in commercial cans of salmon.*

Indol mmg per 100 g salmon	Number of cans classed by odor as					Total
	Good	Slightly stale	Stale	Strongly stale	Tainted or putrid	
0.0—0.5	110	45	48	5	4	212
0.6—1.0	77	55	77	12	15	236
1.1—1.4	7	7	8	3	2	27
1.5—	11	11	18	7	22	69
Total	205	118	151	27	43	544
1.5—	5.36%	9.3%	11.9%	25.9%	51.1%	12.6%

	Reported as good.	Reported as stale.
0.0—0.5 .....	155	53
0.6—1.0.....	132	89
1.1—1.4.....	14	11
1.5.....	22	25
Total.....	323	178
1.5.....	6.81%	14.0%

	Passed by odor as fit for food.	Not passed by odor.
0.0—0.5 .....	208	4
0.6—1.0.....	221	15
1.1—1.4.....	25	2
1.5.....	47	22
Total.....	501	43
1.5.....	9.38%	51.1%

The results show an increasing percentage of cans containing 1.5 mmg (or more) of indol per 100 g of salmon, with an increase in the odor of decomposition. However, a few (5.36%) of the cans classed as good would be condemned on the basis of 1.5 mmg of indol, while nearly half (48.9%) of those condemned by odor would be passed by the indol test. As stated in 6, G, almost none of the cans (from our experimental packs) prepared from fish out of water 48 hours or less, gave a test for more than 1.5 mmg indol, and in those cases the raw fish showed signs of decomposition. It is evident, therefore, that although these few cans had an odor classed as good, considerable decomposition had already taken place. As pointed out in 7, A, many bacteria do not produce indol, although they may bring about a putre-

fraction of the fish. This may explain why such a large percentage of tainted commercial canned salmon contained less than 1.5 mmg indol. The experimental pack of salmon as shown in table 14 contained more indol than the commercial cans examined. The difference may be due to a difference in bacterial flora between the waters of Puget Sound, where the fish for the experimental pack were caught; and the waters of Alaska, where most of the fish for these commercial cans were caught. There may be a larger percentage of indol formers in the flora of the waters of Puget Sound.

In conclusion it may be said that when indol is found in amounts of 1.5 mmg or over per 100 g it is certain that a considerable amount of decomposition has taken place. However, we cannot safely accept the absence of indol as conclusive evidence of the absence of decomposition. In other words, a positive test has considerable value in judging the condition of canned salmon as regards decomposition, while a negative test is of little value.

#### G. *Discussion of the results*

The results obtained in the experimental work on the five species of salmon have been summarized for each species, in tables and figures, in the previous pages of part 6. Furthermore, all of the conditions and changes studied during this investigation have already been discussed to some extent in the general outline of the experiment.

The physical results on each of the species are very similar. All of the indications of decomposition increased in intensity from day to day, and although there were individual fish or cans which did not follow the general rule, the averages for the fish examined from day to day showed a consistent and regular increase in each of these indications; this is shown in the tables giving the average daily decomposition changes. The chum salmon showed more rapid increase in decomposition changes than the others, and this was probably due to the higher temperature at which they were stored during the first two days. In the pink salmon, on the other hand, decomposition proceeded much more slowly; and this again was apparently due to the somewhat lower temperature prevailing at the beginning of the experiments on pink salmon.

The chemical results from the different species are also similar, but here, too, the influence of the storage temperature is very marked, some of the chum salmon giving a test for 1.5 mmg or more of indol at the end of 48 hours, while none of the pinks gave a test for this amount until after 96 hours. In the case of all the species, however,

the amount of indol increased from day to day; and although there were some determinations both of the raw and of the canned salmon which did not follow the general rule, yet the averages for the fish examined each day showed a rather consistent increase. The curves which are given for each species show that during the first two or three days little indol is found; but after it begins to appear in noticeable quantities, the increase is very rapid, or, in other words, the curve bends sharply upward. The curves showing the results obtained from the gills do not show the pronounced initial lag shown by the curves for the flesh, either raw or canned, and this is no doubt due to the fact that the gills contain many bacteria at the beginning of the storage period, while the flesh is free from bacteria. Indol production, therefore, may start at once in the gills, but not in the flesh until after it has been invaded by the bacteria. This invasion, as shown by the bacteriological results, is rather slow for the first 48 hours; this agrees with the indol production. The curves for the viscera in most of the species show a longer initial lag than those for either the flesh or the gills; and the amount of indol in the advanced stages of decomposition of the viscera was less in nearly every case than in the flesh. It may be that the viscera are a poor medium for the growth of bacteria and the formation of indol. Furthermore, the presence of the milt and roe (which are very slow in showing signs of decomposition) in the ground viscera served to dilute the more easily putrescible parts, such as the intestines, stomach, heart, etc., and thus lowering the percentage of indol. Since the bacteriological samples were taken from the intestines only, while the chemical samples included the entire contents of the belly cavity, is it not surprising that the results do not agree very well.

The curves given in Figs. 2 and 3 for king and pink salmon respectively, do not show a good agreement between the raw and the cooked flesh; the raw flesh has more indol than the cooked. As pointed out elsewhere, this is due not to loss of indol in the canning process, but to an unfortunate choice of samples for this determination; the raw salmon used was taken from those parts of the fish most heavily invaded by bacteria, while the canned salmon used represented parts much less heavily invaded. The curves given in Figs. 4, 5, and 6, for sockeye, coho and chum salmon, respectively show very good agreement between the raw and the cooked flesh. This is due to the fact that the raw and canned flesh used for the indol determination came from the same cut of the fish, one half being used raw and the other half canned.

The variation in the amount of indol found in different parts of



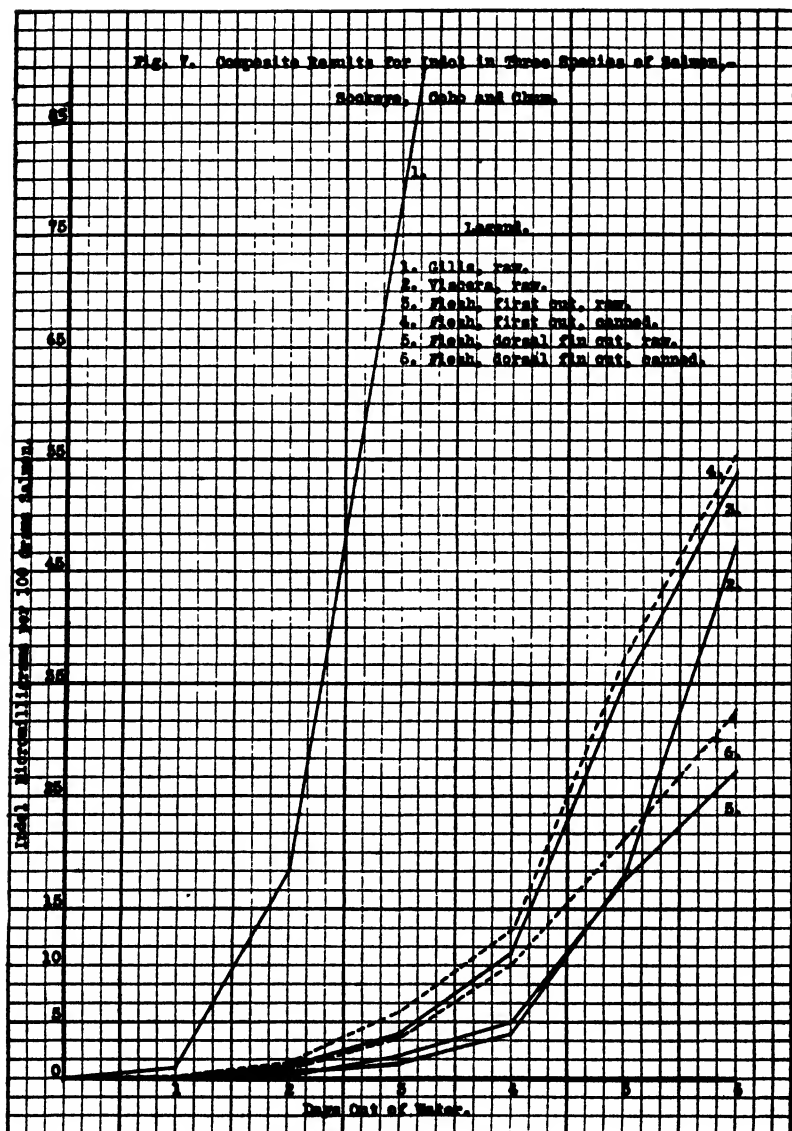


Fig. 7. Composite results for indol in sockeye, coho and chum salmon.

the same fish is shown in Fig. 7, which gives composite curves showing the results from the first cut and those from a cut near the dorsal fin. The first cut contains more indol because it is near the gills where it is quickly and heavily invaded by bacteria. These composite curves show excellent agreement between the results from the raw and the cooked flesh, especially in the first cut. Why slightly more indol was found in the cooked than in the raw flesh is not clear, but it may be that the cooking process serves to break down the cell structure, liberating the indol, resulting in a more rapid and complete distillation.

Figure 8 shows the results from the raw flesh of the five species. The difference in temperature prevailing at the time these different species were under examination may have been partly responsible for the difference in the results obtained. The maximum and minimum temperatures were taken each day, and these have already been given; but for convenience, curves showing the mean temperatures from day to day are also given in Fig. 8. Inspection of these curves shows that the king salmon was stored at the highest average temperature and the coho and sockeye at the lowest. The king salmon contained the most indol, while the sockeye and coho had the least, with the exception of the pink, which had less during the first four days. The chum salmon curve follows that of the king very closely at first; but the rate of increase falls off, and the falling off is coincident with a sharp lowering of the temperature when the chum salmon were moved from the laboratory to the outside of the building. The low temperature prevailing at the beginning of the experiments with pink salmon is no doubt partially responsible for the small amount of indol found during the first four days; while the increasingly higher temperatures toward the end of the storage period, together with their small size, may account for the rather rapid increase in indol content during the fifth and sixth days. Since the sockeye and coho salmon experiments were made at the same time, the temperature was not responsible for the difference in indol content. It is possible that this difference is due to the difference in the average size of the two species; the coho salmon is much larger, so the bacteria would be somewhat longer in invading all parts of the flesh, and the proportion of indol in the flesh would be less. Temperature is without doubt a big factor in the spoilage of salmon, and the correlation between it and indol formation is quite apparent from a study of the curves in Fig. 8.

Skatol was not found in any of the raw salmon, nor in the cans prepared from them; but indol was found in every test made on salmon which had been held for 48 hours or more. An organism capable of

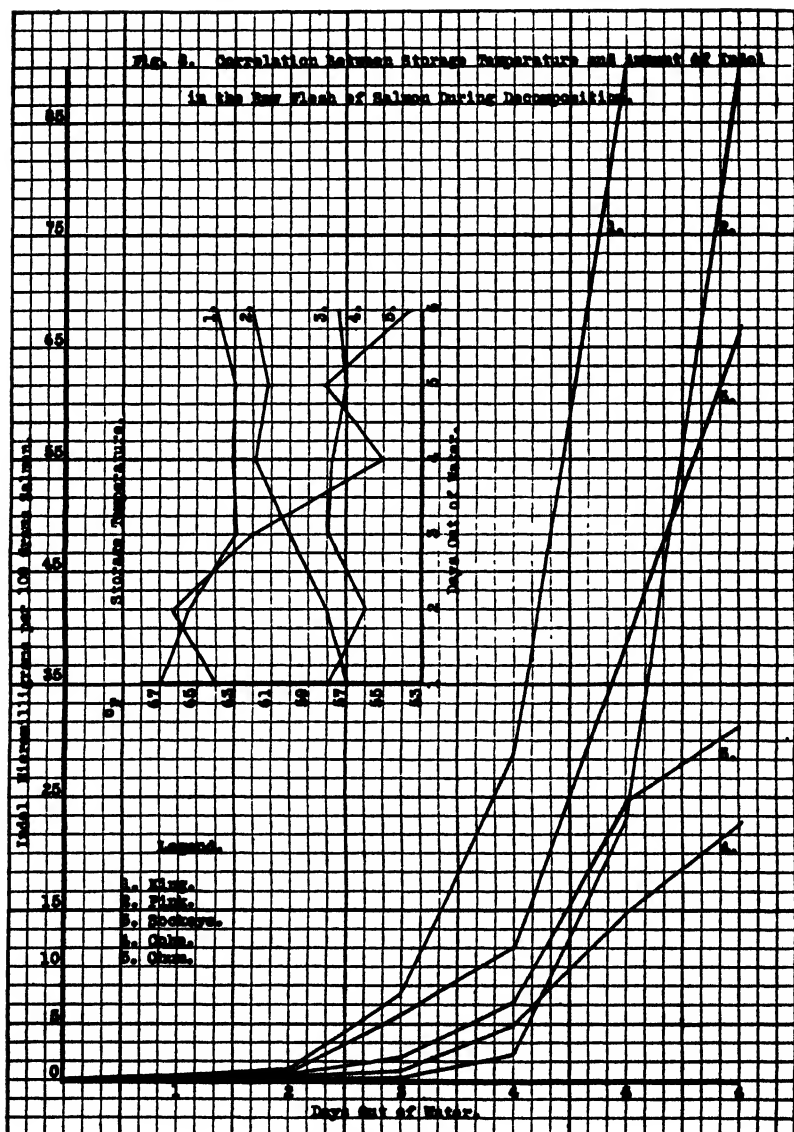


Fig. 8. Correlation between storage temperature and amount of indol.

producing skatol was however isolated from the king salmon (7, A).

The bacteriological results are very similar to the chemical results, as might be expected, since the chemical substances formed during decomposition are due to the bacteria present. However, as is pointed out in a later section, not all bacteria produce indol, and for this reason the correlation between numbers of bacteria and indol content may or may not be a close one. The number of bacteria increased from day to day in each of the parts of the fish examined; gills, viscera, back flesh and belly flesh. The gills contained a large number of bacteria when the fish were drawn from the water, while it is probable that the other three parts of the fish examined were free from bacteria. At the end of 24 hours the gills usually contained several thousand bacteria per gram while the viscera sometimes and the flesh usually was sterile or contained very few bacteria.

The correlation between the bacteriological results and the chemical results has been shown in the tables containing the average daily decomposition changes of the five species of salmon. For convenience these daily averages have been composited and the results expressed in curves in Fig. 9. In general the correlation is very good; the curves for indol and for bacteria, in both the gills and the viscera, have very nearly the same shape throughout. It will be noted that the belly flesh is more rapidly invaded than the back, and this is probably due to the fact that the layer of flesh in the belly is much thinner than that in the back. The curve for indol in the raw flesh falls between the curves for bacteria in the belly and back flesh, due to the fact that the raw flesh was made up of both belly and back flesh. The sharp falling off in the number of living bacteria between the fifth and sixth day indicates that the media had become unfavorable, at least to some of the species of bacteria, with a consequent heavy mortality.

From a consideration of the results obtained in this study of the decomposition of salmon, and from results which were later obtained in a study of the intestinal bacterial flora, it is believed that the spoilage of fish taken while on the spawning migration proceeds primarily from the outside of the fish and not from the digestive tract. Bacteria invade the flesh from the gills, the anus, and the skin. In the case of fish caught while still feeding (by trolling), spoilage will proceed from both the outside and the inside. Correlations between the odor and the indol content in the raw salmon, in our experimentally packed salmon, and in commercial packs of salmon, have been given on previous pages. Correlations between the bacteriological and the chemical results have also been shown, as well as between the indol content and the temperature of spoilage. Correlations between the tempera-

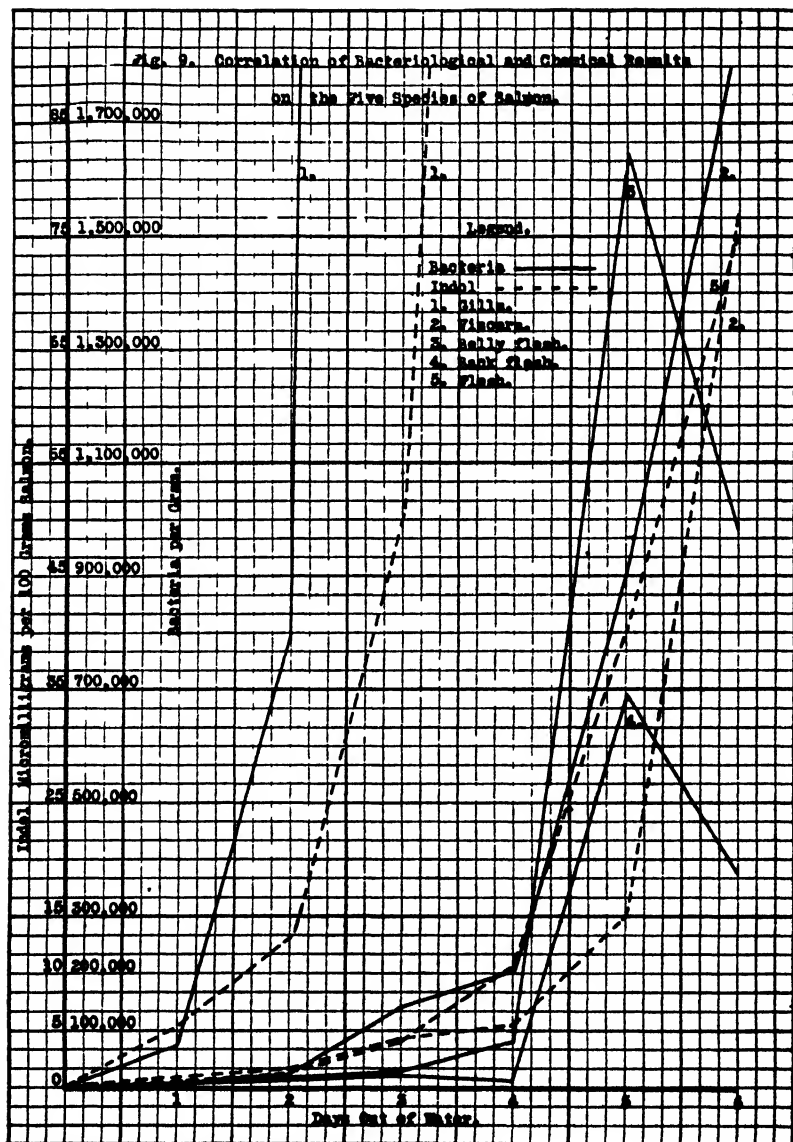


Fig. 9. Correlation of bacteriological and chemical results.

ture, the indol content, the number of bacteria present, and various signs of decomposition, such as reddening, texture, etc., might be shown in a similar way; but enough has been written to show that the physical, chemical and bacteriological changes proceed simultaneously and approximately parallel, and that the rate is dependent to a large extent upon the temperature. Although the indol test cannot supplant the examination by odor and other physical signs of decomposition, it forms, nevertheless, a very useful check on the other methods of examination, and affords considerable information as to the history of the salmon under inspection.

## 7. FORMATION OF INDOL BY VARIOUS MEANS

### A. *Indol formation by bacteria*

So many cases were encountered in the study of both raw and canned salmon, in which the odor and the indol content were not in accord, that it seemed advisable to make a study of the bacteria which Dr. C. R. Fellers had isolated during the above investigation, to ascertain how large a percentage of them would produce indol in Dunham's peptone solution. In many cases cans classed by odor as "slightly stale", or even as "good", were found to contain as much indol as other cans which were classed as "tainted"; and on the other hand, cans having a tainted odor sometimes did not give a test for either indol or skatol. Since the foul odor must be due to bacterial decomposition, it is evident that spoilage may proceed without the formation of these specific products. Rettger (1906, 1908), in his work on putrefaction, states that true putrefaction is due to strict anaerobes alone, and indol is seldom formed. Furthermore, *Bacillus botulinus*, a strict anaerobe, was inoculated for experiment into some sterile cans of salmon, then the cans exhausted and again sealed. After standing about two days at the temperature of the laboratory, the cans showed a pronounced swelling; on opening, they were found to possess a putrid odor; in fact, the contents of each can was in a liquid condition and bubbling with gas. No indol was found in any of these cans.

The bacteria used in the determination of indol production were derived from the following five sources: 1. Isolated from the five species of salmon (raw) during the study of decomposition. 2. Isolated from commercially canned salmon. 3. Taken by the writer from raw salmon (gills, viscera, flesh and pugh marks) at various points in central and southeastern Alaska. 4. Taken by Dr.

C. R. Fellers from four species of salmon (raw) at Blaine, Washington. Taken from points just in front of and just behind the stomach, to ascertain whether the intestinal tract of salmon on the spawning migration is sterile. A few cultures were also made from the gills and pugh marks. 5. Taken from chum salmon which had been held frozen in cold storage for three months.

The method of experimentation was to inoculate the bacteria into 10 cc of Dunham's peptone media and incubate at 37° C. for one week. The tube was then emptied into a 250 cc Fry flask and washed out with 40 cc of water. A current of steam was passed through and 100 cc of distillate collected. This was acidified with 2 cc concentrated HCl and extracted once with 50 cc of ethyl ether in a 300 cc separatory funnel. The ether was washed in the same separatory funnel with 5 cc NaOH (2.5%) and 5 cc dilute HCl. The ether was evaporated over 10 cc water and 5 cc of the water tested for indol by the method given in 5, B. In order to determine the percentage of recovery of indol in the first 100 cc of distillate, a culture tube inoculated with an organism from the pink salmon was incubated for a week and then distilled. Ninety four per cent of the total amount recovered was secured in the first 100 cc. These results indicated that it was not necessary to distill more than 100 cc.

In the summary (table 16) the percentage of indol producers ranges from 0 to 66. The lowest percentages are from bacteria from

TABLE 16. *Summary of indol production by bacteria from raw and canned salmon.*

Source	Species	Months since bacteria taken	No. organisms tested		Indol positive	Skatol positive	—Total— positive	
			No gr'th	Growth			No.	Per cent
1	King	13	3	40	2	1	3	7.2
1	Red	11	10	12	0	0	0	0
1	Coho	11	9	8	0	0	0	0
1	Pink	12	7	25	7	0	7	28.0
1	Chum	10	1	20	9	0	9	45.0
2	All		6	51	9	0	9	17.6
3	All	2	4	36	16	1	17	47
4	King	1		20	10	0	10	50
4	Pink	1		31	17	0	17	54
4	Red	1		24	15	1	16	66
4	Chum	1		9	5	0	5	55
5	Chum	1		23	0	0	0	0
Total				299	90	3	93	31

sources where they have been subjected to unfavorable environment, such as low storage temperatures, long period of cultivation on artificial media, etc. The bacteria in source 5 are those hardy enough to survive cold storage temperatures for three months; apparently all the indol producers were killed by this treatment. The bacteria from the red and coho salmon, source 1, had been on artificial media for 11 months and had been transferred only twice, while those from the other three species had been transferred three times. Several of the cultures were apparently dead, since they gave no growth in Dunham's media. The bacteria found in canned salmon were the survivors of a rather rigorous treatment. The spore-formers are of course the ones most likely to survive hardship, and it would seem that as a class they are not as likely to produce indol as the non-spore-formers. Even under the most favorable circumstances only 66% of the bacteria taken from raw salmon produced indol, while some of those which did not form indol produced a putrid odor. It is therefore easily possible for bacteria to decompose salmon without the formation of indol or skatol. Regarding this, Effront says: "We may conclude from the preceding that the presence of indol is not an infallible characteristic of putrefaction. Numerous aerobes and even certain anaerobes, like *B. putrificus*, which cause the disintegration of albumin to the most simple substances, do not, however, yield phenol or indol. The production of indol indicates merely a mode of attack, a particular direction given to the dismemberment. In other words, it corresponds only to the secretion of an amidase specific for this transformation."

Skatol formation by bacteria was induced (table 16) by only 3 of the bacteria studied in this investigation, when growing in Dunham's media, while 90 formed indol. It is possible that all those bacteria forming indol might, under a different set of conditions, form skatol; but it seems more probable that in those tests in which skatol was formed there was present a specific skatol-forming organism. Such an organism was isolated from culture No. 32 taken from raw king salmon (source 1) and was found to be identical with an organism isolated from canned macaroni. No description of this microorganism has been found in the literature, and it is probably a new species. It is a large, rod-shaped, motile bacterium which, on sporulation, becomes clostridium-shaped, with a large cylindrical spore. It is an obligate anaerobe but has been grown in paraffin-stratified broth in association with a facultative anaerobe from which it has been found rather difficult to separate it. The facultative anaerobe is also rod-shaped, mo-



tile, gram-positive, and spore-forming; it is able to grow in oxygen tensions from almost zero to atmospheric.

### B. *Formation of indol by scorching proteins*

Rohmann (1908) states that both indol and skatol may be formed from tryptophan by heat. Since salmon flesh carries tryptophan, it appeared that scorching might produce indol in perfectly fresh salmon. This had two important bearings on our problem; first, the possibility of indol formation during the distillation in the indol determination, and second, its possible formation during the commercial canning of fish. The first possibility is discussed here, and the second in 7, C. To eliminate the possibility of the formation of indol during its distillation from salmon, the distilling flask was never heated over a free flame but in a bath of nearly saturated salt solution.

To test the effect of scorching on salmon and other proteins, several experiments were carried out among which was the following one. Various substances containing protein were scorched in tin cans, transferred to flasks and distilled in the usual way. The distillates were extracted with ether, which was washed and evaporated. The water test solutions were divided into two parts, one of which was tested with Ehrlich's reagent, and the other with the Vanillin-HCl reagent. The colors produced by the former reagent were extracted four times with chloroform and the residual color noted. The results are given in tables 17 and 18.

TABLE 17. *Color produced by Ehrlich's reagent in the indol test on various scorched foods.*

Substance scorched	Initial color.	Extractions with chloroform				Residual color equivalent to
		1.	2.	3.	4.	
Peas, canned	Slight; like indol	Pink	Slight	Very sl.	None	1 mmg indol
Beans, canned	Strong; purple; like indol	Pink	Pink	Slight	Very sl.	1 mmg indol
Eggs, fresh	Very strong; purple; like indol	Very strong pink	Strong pink	Pink	Slight	3 mmg indol
Salmon, canned	Strong, purple; like indol	Pink with orange	Violet	Pink	Trace	1 mmg indol
Gelatin, Knox	Strong; more purple than the others	Slight orange	Slight violet	Trace	None	Strong dark purple color; over 20 mmg indol

TABLE 18. *Color produced by the vanillin-HCl reagent in the indol test on various scorched foods.*

Substance scorched	Colors produced
Peas, canned -----	Weak color; looks about right for indol
Beans, canned -----	Stronger color than produced in the case of the peas; looks like the color produced by indol
Eggs, fresh -----	Very strong color; correct for indol
Salmon, canned -----	Strong color; correct for indol
Gelatin, Knox -----	Strong color; looks almost like the indol color.

It appears that either indol, or a substance resembling it very closely, is formed by the scorching of those proteins which contain the tryptophan group. Gelatin does not contain this group, but a color is obtained from the scorched gelatin by both the Ehrlich and Vanillin tests which closely resembles the color produced from other scorched proteins which do contain the tryptophan group. However, since the color produced by the Ehrlich test did not extract with chloroform in the case of gelatin, but did in the case of all the other proteins tried, it appears that the color produced from gelatin was not due to indol.

### C. *Formation of indol during the processing of salmon.*

Since indol apparently may be formed by scorching salmon, it seemed desirable to determine whether it may be formed during the commercial processing of salmon. This did not seem probable, but in order to be able to state definitely that indol found in cans was the result of bacterial action and not of the cooking process, it was necessary to prove or disprove the possibility of its formation during processing.

A piece of fresh king salmon was obtained and ten half pound (227 g) cans filled. These were tightly closed and immediately placed in the pressure cooker, where they were cooked for 90 minutes at 240° C. The cans were then removed from the cooker and cooled. Eight cans were recooked and cooled as before. The same process was repeated on six cans, then on four, and finally on two. So that cans which had been cooked one, two, three, four and five times, were obtained. Five of the cans representing the five periods of cooking were opened, carefully examined, and the indol determined. The other five cans were later used in the determination of volatile nitrogen. The raw fish used, when tested for indol, gave a negative test. The experiment was repeated, and the results are given in table 19.

The indol is expressed in mmg per 100 g of salmon, Ehrlich's reagent used.

TABLE 19. *Formation of indol during the processing of salmon.*

Experiment	In raw fish	1st cook	2nd cook	3d cook	4th cook	5th cook
1	0.0	0.3	0.6	0.8	1.0	1.3
2	0.1	0.3	0.6	0.6	1.1	1.2

A small amount of indol is apparently formed during the processing of salmon but the amount formed during the usual processing (1st cooking above) is so small as to be practically negligible. The amounts obtained from successive cookings show a gradual and regular increase. The odor varies from normal, through slightly scorched to strongly scorched, while at the same time the fish takes on a scorched flavor. The color grows gradually poorer and the texture softer. The indol color extracted well with chloroform in each case.

*D. Effect of exhaust on the indol content of canned salmon.*

Most of the canned salmon is exhausted before the cans are tightly closed and placed in the retorts. This is usually accomplished by passing the filled cans through a steam box either without the tops or with the tops loosely clinched on. During this process the contents of the can becomes heated, and a part of the air is expelled, resulting in a partial vacuum after the cans are tightly closed, cooked and cooled. The question arises as to the effect of this exhaust on the indol content and the odor of canned fish. Several experiments were carried out, using king, pink and chum salmon in various stages of decomposition. Each fish was cut into sections containing slightly more than one pound (454 g) each. These sections were divided into two equal pieces and each piece placed in a half pound (227 g) can. The cans were marked as usual to show the fish and section, and in addition the cans from one side were marked "E" and those from the other side "N". The covers of the cans marked "E" were loosely clinched and the cans placed in steam at 100° C. (212° F.) for 12 minutes, when the covers were tightly rolled on. The cans marked "N" were tightly closed while the cans were cold. All of the cans were cooked for 80 minutes at 115.5° C. (240° F.)

After the cans had been stored for a few weeks they were examined according to our usual method. The odor of the cans was noted very carefully by three to five men acting independently and without knowing which cans were exhausted and which were not.

The odor of stale and tainted salmon is apparently slightly improved by exhausting the can; for when the separate results of the different examiners were compared it was found in nearly every case that the can in each pair which had been adjudged slightly better in odor was the exhausted can. The indol content in the two cans taken from the same section of the fish, while frequently markedly different, also showed this difference to be as often in favor of the exhausted can as of the unexhausted can. Averages for exhausted and unexhausted cans were nearly equal in most cases. Apparently, therefore, exhausting the can has little effect on the indol content.

### 8. OTHER DECOMPOSITION CHANGES

An attempt was made to use some of the other decomposition changes and products as measures of decomposition. As stated before, ammonia is without doubt formed from the amino acids during decomposition. However, there is good reason to believe that it may also be formed during the cooking process, creating a doubt as to the origin of the ammonia found in the can. Fatty acids may be formed progressively from fats during decomposition, but it is certain that they may also be formed by heat and pressure. Whether the cooking process in the case of salmon is severe enough to bring about this hydrolysis is a question to be settled by experiment. During the decomposition of salmon a peculiar substance is formed which produces a strong biting sensation when placed on the tongue; it also attacks the skin on the back of the hand. This substance is mentioned in 2. An attempt was made to isolate it.

#### A. Volatile nitrogen as a measure of decomposition

There are several methods for determining the volatile nitrogen based on distillation or on aeration. The methods used by Loomis (1912) employed distillation from an alkaline medium into standard acid, while Weber (1921) used a modification of the Folin aeration method. The latter method is given by the Assoc. Off. Agric. Chemists (1919) as tentative, and was selected, with certain modifications, for our use. On account of the lack of time, no work was done on the distillation methods. Leach (1920) recommends the use of alcohol in the aerating cylinder, and this was found to reduce the frothing to some extent. The apparatus used consisted of six complete units, so that three determinations in duplicate could be made simultaneously. The air was passed through under pressure, first being

washed in a cylinder containing concentrated sulphuric acid. From the washing cylinder the air passed through six rubber tubes provided with regulating pinch cocks, was conducted by glass tubes to the bottom of the aeration cylinders, and after bubbling up through the mixture of fish and chemicals, was passed through the Folin absorption tube into N/50  $H_2SO_4$  contained in a 250 cc graduated cylinder. The apparatus, as purchased, provided for the use of bottles four inches (10.2 cm) high for the absorption of the volatile nitrogen compounds; but experiments showed that a much smaller volume of air could be passed through these bottles than through the 250 cc cylinders, and consequently the time of aeration would need to be correspondingly increased.

Twenty five grams of finely ground fish was placed in each aeration cylinder with 150 cc of water, 1 cc of saturated potassium oxalate solution, 25 cc of alcohol, a few drops of phenolphthalein and enough saturated potassium carbonate solution to render the mixture alkaline. Air was passed through as rapidly as possible for six hours and the acid in the absorption cylinder titrated against N/50 NaOH, using sodium alizarinsulphonate as an indicator.

Experiments were now performed to determine whether there was an increase in volatile nitrogen during decomposition, and also whether volatile nitrogenous compounds were formed during the cooking process.

The increase in volatile nitrogen during decomposition was tested by using samples taken from the experimental packs of salmon in various stages of deterioration as described in 6. Of course all of these samples were canned, so when comparing the results it is necessary to assume that if volatile nitrogenous compounds were formed in the canning process the same amount was formed in each of the cans used. The five species were used; the chemical results are given in table 20.

TABLE 20. *Volatile nitrogen in salmon canned at different stages of decomposition.*

Hours out of water when canned	Volatile nitrogen mg per 100 g of fish					
	Pink	Sockeye	Chum	King	Coho	Average
24	17.3	22.3	25.4	34.0	40.9	28.0
48	21.6	19.7	31.7	37.9	38.5	29.9
72	24.3	24.6	35.1	33.8	43.6	32.7
96	32.3	26.1	29.7	37.9	48.4	31.3
120	44.5	41.4	36.6	46.3	55.4	44.8
144	54.3	45.1	47.1	40.4	55.3	48.4

The results show a rather consistent increase in volatile nitrogen from day to day during decomposition in each of the five species. There are a few instances in which the amount decreases; but it must be remembered that a different fish was used for each can, and that some of the fish examined on one day appeared to be in better condition than some of those which were examined and canned the day before. Furthermore, the volatile nitrogen formed during the cooking and during storage must be considered. For the purpose of correlation the amount of indol in these cans was also determined and is given in table 21.

TABLE 21. *Indol in salmon canned at different stages of decomposition.*

Hours out of water when canned	Indol mmg per 100 g of fish					
	Pink	Sockeye	Chum	King	Coho	Average
24	Lost	0.2	0.2	0.1	0.1	0.15
48	"	1.0	1.8	0.8	0.6	1.05
72	"	3.0	4.5	3.3	1.3	3.0
96	"	10.0	16.0	20.0	7.6	13.4
120	"	22.5	52.0	24.0	15.7	28.5
144	45.0	50.0	80.0	22.0	16.0	42.6

Both the indol and the volatile nitrogen increase; but since the former starts from almost zero while the latter starts from an unknown quantity which depends upon the factors of cooking and storage, it is obvious that indol possesses advantages over volatile nitrogen as a measure of decomposition.

The increase in volatile nitrogen during the cooking process was now investigated. Fresh salmon was obtained, the volatile nitrogen determined on a portion, and the rest placed in two half-pound (227 g) cans, one of which was given the usual cooking (80 minutes at 115.5° C., or 240° F.) and the other cooked twice. The volatile nitrogen in each can was then determined. The determinations were made in duplicate. A great deal of difficulty was experienced in the determination of volatile nitrogen in raw salmon on account of excessive frothing. Paraffin oil, kerosene, alcohol and other materials were used, as were various types of baffle plates, but the frothing continued. Although this experiment was repeated several times, only once could results be obtained with raw salmon on account of this frothing. These results are given in table 22.

TABLE 22. *Increase in volatile nitrogen during the canning process.*

Description of sample	Volatile nitrogen, mg per 100 g
Raw salmon -----	11.6
Salmon cooked once-----	22.8
Salmon cooked twice-----	34.0

The results are remarkably uniform and show that cooking splits up the nitrogenous compounds and forms volatile alkaline substances.

Some of the cans which had been packed for the determination of the amount of indol formed in salmon during the canning process (7, C) were used for the determination of volatile nitrogen. These cans had been cooked from one to five times the normal cooking process. Unfortunately no determination of the volatile nitrogen was made in the raw fish; but the indol determination was practically negative, indicating that the fish used was in good condition. The results are given in table 23.

TABLE 23. *Increase in volatile nitrogen during repeated processing.*

Description of sample	Volatile nitrogen, mg per 100 g
Cooked once -----	45.1
Cooked twice -----	45.7
Cooked 3 times-----	56.8
Cooked 4 times-----	57.9
Cooked 5 times-----	64.2

These results show a slight increase for each successive cooking, demonstrating that volatile nitrogenous compounds are split off by it. The amount found after the first cooking is much higher than given in table 22; this difference may be due to the fact that the samples used had been in the cans for nearly a year. Weber and Wilson (1919), when working on canned sardines, found the volatile nitrogenous compounds to increase during storage. This increase might explain why the increase from one cooking to another in table 23 was so much less than in table 22, since more ammonia might be formed during storage in those cans which had the smallest amount at the beginning of the storage period.

The results of both experiments show that the cooking process does increase the volatile nitrogenous constituents of salmon. The

results also tend to confirm the report of Bidault and Couturier (1920) that the amount of ammonia in canned meat is a function of the heat of sterilization.

*B. Increase in free fatty acids as a measure of decomposition in salmon.*

Weber (1921), in his work on the Maine sardine, determined the fat and the free fatty acids in sardines which had been held in brine for periods ranging from 2 to 96 hours, and concluded that no change of a significant nature was shown by the results. However, we made a few experiments, none of which gave satisfactory results.

The first method used was based on that of Folin and Wentworth (1910) for the determination of fat and fatty acids in feces. The cans of salmon used were opened, carefully examined, and then thoroughly mixed. Ten gram portions were weighed out on lead dishes and dried in a vacuum oven at 80° C., cooled and weighed. The lead dishes containing the dried salmon were then placed in Soxhlet extractors and extracted for 16 hours with anhydrous ether containing sufficient anhydrous HCl to make the ether solution approximately tenth normal. The ether was distilled from the flasks and petroleum ether added. After standing over night the petroleum ether solution was filtered into a weighed flask and the residue washed with petroleum ether. The petroleum ether was then evaporated; the residue weighed, dissolved in benzene, and titrated with N/10 sodium ethylate, using phenolphthalein as an indicator.

This method did not prove satisfactory and the experiments were repeated using anhydrous ethyl ether instead of the ether-HCl solvent.

In the investigation of the free fatty acid in salmon canned at different stages of decomposition, the cans used were part of the experimental pack of king salmon described in 6, B. Two portions of each were taken from each can, one portion (*a*) was extracted with the ether-HCl solvent and the other (*b*) with ether alone. The results are expressed as milligrams of stearic acid per gram of fat in table 24.

The results for solids are uniformly higher in the (*b*) samples than in the (*a*) samples; this is due to the fact that the (*b*) samples were secured after the ground fish had been standing exposed to the air for an hour and had apparently lost some of the moisture. The fat is also higher in most of the (*b*) samples. The results for fatty acids are very contradictory. The results for the (*a*) samples are higher than those for the (*b*) samples, except in the case of K2, and



TABLE 24. *Solids, fats, and fatty acids, in king salmon canned at different stages of decomposition.*

Can No.	Hours out of water before canning	Solids, per cent	Fat, per cent	Fatty acids as stearic acid mg per g fat
A2	24	(a) 39.70	17.00	114.2
		(b) 39.89	17.25	74.0
D2	48	(a) 39.96	14.63	102.9
		(b) 40.41	16.92	37.7
G2	72	(a) 44.65	24.50	135.5
		(b) 45.12	21.15	70.0
K2	96	(a) 39.56	17.16	93.7
		(b) 40.24	17.81	113.2
N2	120	(a) 38.67	15.55	95.2
		(b) 39.90	16.32	70.4
P2	144	(a) 38.67	13.74	115.2
		(b) 39.44	14.22	96.9

suggest two possibilities; either the acid in the ether-HCl solvent partially hydrolyzed the fat, or else the HCl was not entirely removed when the ether was evaporated. Even the (b) samples, with which no HCl was used, do not show a consistent increase during decomposition. The method appears to be of little value as a measure of decomposition in canned salmon.

In the investigation of the free fatty acid in salmon before and after canning, portions of a fresh king salmon were used. The solids, fats and fatty acid were determined both before and after canning. Anhydrous ether was used for extraction. The results are given in table 25.

TABLE 25. *Free fatty acid in salmon before and after canning.*

Description of sample	Solids, per cent	Fat, per cent	Fatty acids as stearic acid mg per g fat
Raw salmon -----	25.64	5.36	47.6
	25.64	5.31	23.8
Canned salmon -----	31.95	9.18	13.9
	31.94	9.11	14.0

The results are not favorable to the theory that the fatty acid is

increased during the canning process, but the data is of course too meager to warrant the drawing of definite conclusions.

The amount of free fatty acid was also determined in some king salmon which had been cooked one, three and five times. These cans were a part of those described in 7, C. The results are given in table 26.

TABLE 26. *Effect of cooking on the free fatty acid content of canned salmon*

Description of sample	Fat, per cent	Fatty acids as stearic acid mg per g fat
Cooked once -----	7.94	173.5
Cooked 3 times-----	8.24	170.5
Cooked 5 times-----	6.45	205.8

The results do not show a satisfactory correlation between the number of times cooked and the amount of free fatty acid.

The three experiments described above indicate that the determination of the free fatty acid is not likely to be of value in detecting decomposition in canned salmon.

### C. *Formation of a substance having a biting taste.*

Tainted canned salmon, when placed on the tip of the tongue, produces a sensation similar to that produced by "strong" cheese. If the salmon be rubbed on the back of the hand the skin becomes irritated and itches. Canned salmon in good condition does not produce these sensations. Some new substance has been formed during the decomposition. The same substance, or at least one giving the above sensations, is found in partially decomposed tuna. In both cases its presence appears to be associated with "honey-combing." Several attempts were made to isolate the substance; but although it was obtained in a highly concentrated form, as judged by the effect on the tongue, it was never obtained in a pure state.

## 9. SUMMARY

The canning of salmon constitutes one of the most important industries of the Pacific coast of North America. Salmon, in common with other fish, are delicate, easily injured and very easily decomposed; and there are many opportunities for spoilage between

the time they are taken from the water and the time they are canned. A systematic method for the examination of canned salmon has long been needed, and such a method is herein outlined.

The literature on the chemical composition of fish flesh is reviewed. Original data are given, with food value, based on the analysis of 643 cans of salmon comprising individual fish of the five species from each important canning district. The decomposition of fish flesh together with the utilization of certain decomposition products as a means of estimating the amount of spoilage is discussed. Indol and skatol are the products finally selected as the most suitable for this purpose.

The principal color tests for indol and skatol are given; the Ehrlich, Herter and dimethylaniline tests are chosen as the most sensitive. These three tests are modified and improved and their delicacy increased; a method for the determination of indol and skatol in salmon is developed.

A biochemical study is made of the five species of salmon, covering the physical and bacteriological changes, and the appearance and increase of indol and skatol during progressive decomposition. Data regarding the 138 salmon studied along each of the above lines of investigation are given in tables showing the average daily decomposition changes, and in curves showing the increase in indol. Skatol was not found in any of the raw salmon, or in the experimental cans prepared from them; but was found in several commercial cans of salmon. An organism capable of forming skatol in salmon flesh was, however, isolated from one of the raw king salmon. Indol was found in small amounts in each of the salmon examined at the end of 48 hours storage, but only three of them contained more than 1.5 mmg per 100 grams. In general it may be said that when this quantity of indol is found in canned salmon a considerable degree of decomposition has taken place.

Indol was quantitatively determined in 544 commercial cans of salmon. As some of these cans had a strong tainted odor and yet contained very little indol, the absence of indol cannot be taken as complete evidence that decomposition has not taken place. The experimental or laboratory packs of salmon contained more indol than commercial packs; all experimental cans classed as tainted contained more than 1.5 micromilligrams per 100 grams.

Rather close correlation was found between the number of bacteria present from day to day during spoilage and the indol content; this is shown by means of curves. A close correlation was

also found between the storage temperature and the indol content; king salmon stored at the highest temperature had the most indol, while the sockeye and coho salmon stored at the lowest temperature had the least.

The gills were found to have more bacteria and more indol than either the viscera or flesh. The flesh was sterile at the end of 24 hours in most of the fish examined, and contained little or no indol. The cooked flesh appeared to contain slightly more indol than the raw, but this may be due to the action of the cooking process in breaking down the cellular structure of the fish, resulting in a more rapid and complete liberation and distillation of the indol. The first cut of the fish, just behind the gills, was found to contain more indol than a cut through the middle of the fish in the region of the dorsal fin.

Exhausting the cans of stale and tainted fish was found to improve slightly their odor, but there was apparently no change in the indol content. Indol, or a substance very closely resembling it, is apparently formed by the scorching of those proteins, including salmon flesh, which contain the tryptophan group. A small amount of indol may be formed during the processing of salmon, but this amount is so small as to be negligible. Excessive cooking produces slightly more indol, a scorched odor and flavor, and a slightly softer texture.

The indol producing power of 299 different cultures of bacteria taken from raw or canned salmon was tested and only 31 per cent gave positive tests. The comparatively small number of these bacteria which produced indol, suggests a reason why so large a percentage of the tainted commercial cans contained little or no indol.

The canning process appears to increase the amount of volatile nitrogen (ammonia and amines) in salmon. The volatile nitrogen content of salmon increases from day to day during decomposition with considerable regularity; but owing to the probability of its formation during the cooking process, it is not suitable as a measure of decomposition in canned salmon, although no doubt it is of value as a criterion in the case of raw salmon.

Very unsatisfactory results were obtained in attempting to use the free fatty acids of salmon oils as a measure of decomposition of the fish from which they were extracted. Tainted canned salmon, when placed on the tip of the tongue, produces a sensation similar to that produced by "strong" cheese. A substance producing this sensation was obtained in a highly concentrated but impure form,

and the attempt to identify it was abandoned on account of lack of time.

In conclusion it may be said that although the determination of indol cannot supplant odor and physical appearance in the examination of canned salmon, it is nevertheless of value and affords considerable information as to the previous history of the sample.

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# PUBLICATIONS PUGET SOUND BIOLOGICAL STATION

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## ANNOUNCEMENT

The *Publications Puget Sound Biological Station* of the University of Washington appear irregularly. The pages and plates are consecutive throughout a volume. The subscription price is \$3.50 per volume of about 400 pages. For information address Dr. T. C. Frye, University of Washington, Seattle, Washington.

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## **Hermit Crabs of Friday Harbor, Washington**

BELLE A. STEVENS

*University of Washington*

The aim of this paper is to describe and figure the species of the family Paguridae in so far as found in Puget Sound, Washington. The paper is based on material collected by the writer in the Friday Harbor region during the summers of 1922 and 1923. Figures 25-41 are inserted to illustrate the general appearance and the appendages of a typical hermit crab.

In addition to the literature listed in the brief synonymy under each species the following papers have been very helpful in the preparation of this article:

Alcock. Catalogue of Indian Decapod Crustacea; Pagurides; Part 2, fasc. 1, pp. 11-197, pls. 1-16, Indian Museum, Calcutta, 1905.

Faxon. The Stalk-Eyed Crustacea; Mem. Mus. Comp. Zool. Harvard, Vol. 18, 1895.

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Milne-Edwards & Bouvier. Descriptions des Crustacés de la Famille des Paguriens Recueillis Pendant L'Expedition du "Blake", Mem. Mus. Comp. Zool. Harvard, Vol. 14, No. 3, 1893.

The color descriptions are based on an examination of live material, and the terminology used is almost entirely according to Robert Ridgway's Color Standards and Nomenclature, 1912.

Acknowledgments are due to Professor Trevor Kincaid of the University of Washington, Dr. Robert H. Wolcott of the University of Nebraska and Dr. Waldo L. Schmitt of the Smithsonian Institution, Washington, D. C.

Naturally the descriptions and keys are much as in the authors to whom reference has been made, but it is not expedient to set all these off as quotations.

The author realizes that this paper is very limited since the collection was made over a comparatively small area, but hopes it may serve as a beginning in the study of the Puget Sound representatives of this group.



The hermit crabs are Crustaceans belonging to the sub-class Malacostraca, series Eumalacostraca, division Eucarida, order Decapoda, suborder Reptantia, tribe Anomura and family Paguridae.

### Family Paguridae

Abdomen soft, showing no trace of segmentation, straight, twisted or spirally coiled; some of the appendages lost, the remainder much reduced; tail-fan not adapted for swimming, adapted for holding the body into hollow objects. Carapace firm in fore part and soft in hinder part. First pair of legs chelate; fourth pair unlike the third.

#### *Synopsis and Key to the Genera*

- A. Right cheliped larger than the left; external maxillipeds widely separated at base.
  - B. Fingers of chelipeds opening and closing horizontally; no paired appendages on first or second abdominal segment of either sex. PAGURUS, p. 274.
  - BB. Fingers of chelipeds opening and closing obliquely; a pair of appendages on the first abdominal segment of the female only. PYLOPAGURUS, p. 296.
- AA. Chelipeds equal or subequal or the left larger than the right; external maxillipeds approximated at base. PAGURISTES, p. 299.

#### Genus PAGURUS Fabricus

Without paired appendages, except the uropods on the abdomen of either sex; external maxillipeds widely separated at base; exopodites of all three pairs of maxillipeds flagellate; chelipeds usually dissimilar and unequal, the right being much the larger, very rarely are they subequal; fourth pair of legs subchelate.

#### *Key to the Species*

- A. Hands roughened above; carpus of large cheliped in adult about as broad or narrower than hand.
  - B. Hands granulate above or mostly so.
    - C. Hands granulate only; large hand elongate and little if any broader than carpus.
      - D. Hands hairy. P. HIRSUTIUSCULUS, p. 281.
      - DD. Hands not hairy. P. GRANOSIMANUS, p. 282.

- CC. Hands granulate and tuberculate; large hand sub-orbiculate and decidedly broader than carpus.  
P. TENUIMANUS, p. 293.
- CCC. Hands granulate and spiny; large hand elongate and little broader than carpus.
- E. Dactyls of ambulatory legs having a distinct sulcus on upper surface. P. ALEUTICUS, p. 278.
- EE. Dactyls of ambulatory legs not having a sulcus on upper surface. P. ALASKENSIS, p. 277.
- BB. Hands spiny or tuberculate above or mostly so.
- F. Hands with spines only; fingers of small hand little if any longer than palm.
- G. Ambulatory legs practically without hairs; spines of hands slender. P. OCHOTENSIS, p. 279.
- GG. Ambulatory legs decidedly hairy; spines of hands stout.
- H. Hair of hands scarcely as long as spines.  
P. KENNERLYI, p. 289.
- HH. Hair of hands much longer than spines.  
P. SETOSUS, p. 290.
- FF. Hands with tubercles only; fingers of small hand nearly twice as long as palm. P. SPLENDESCENS, p. 295.
- FFF. Hands with short spines and spiny granules; fingers of small hand little if any longer than palm.
- I. Merus of right cheliped with 2 prominent tubercles below. P. BERINGANUS, p. 283.
- II. Merus of right cheliped without prominent tubercles below.
- J. Carpus of right cheliped about twice as long as wide; merus joints without sharply defined band of white near distal end.  
P. BRANDTI, p. 285.
- JJ. Carpus of right cheliped less than twice as long as wide; merus joints with sharply defined band of white near distal end.  
P. DALLI, p. 287.
- AA. Hands smooth above; carpus of large cheliped in adult much broader than hand.  
P. GILLI, p. 291.



Fig. 1. *Pagurus alaskensis* (Benedict).  $\times 1$ .

**PAGURUS ALASKENSIS (Benedict). Figs. 1, 25-41.**

*Eupagurus bernhardus* var. *B. granulata denticulata?* Brandt, Middendorff's Sibir. Reise. Zool., p. 107, 1851.

*Eupagurus bernhardus* Stimpson, Boston Journ. Nat. Hist. 6:483, 1857.

*Eupagurus alaskensis* Benedict, Proc. U. S. Nat. Mus. 15:2, 1892.

*Pagurus alaskensis* Holmes, Occas. Papers Calif. Acad. Sci. 7:135, 1900; Benedict, Proc. U. S. Nat. Mus. 23:456, text fig., 1901; Rathbun, Harriman Alaska Exped. 10:157, 1904.

**Characters.**—Anterior portion of carapace somewhat wider than long; median tooth triangular and acute; lateral teeth shorter and rounder but armed with a small spine. Eye stalks short, stout, constricted in the middle and about half the length of the anterior portion of the carapace. Antennal acicle exceeds the tip of the eye by about one-fourth its length, inner margin armed with 12 to 16 short, conical teeth and set with bunches of hairs. Chelipeds unequal, granulated and spinulose, especially along the inner margin of the carpal joints, and almost devoid of pubescence. Carpus of small cheliped 4-sided; dactyl longer than the palm. Ambulatory legs with merus and propodus spinulose above; dactyls long, flat and twisted.

**Color.**—Iridescent or opalescent with a golden sheen, below sea-shell pink to apricot orange. A mahogany red streak runs around the prehensile edge of the thumbs and behind the dactyls to the anterior margins of the hands. Merus and basipodite of chelipeds and ambulatory legs with irregular patches of madder brown, spines on the hands madder brown to apricot orange. Dactyls and propodi of ambulatory legs longitudinally streaked with madder brown. In very large specimens the opalescence is largely replaced by wistaria violet, particularly at the distal end of the joints and along the upper surface of the ambulatory legs. Antennal acicles pearly iridescent.

**General Distribution.**—Siberian and Alaskan coasts of Bering Sea to Oregon; beach to 248.7 meters (Rathbun).

**Local Distribution.**—Rather common. Numerous northeast of Canoe Island at 27 to 37 meters; in Squaw Bay off Shaw Island at 9 meters; both north and south of Flat Point at 27 to 49 meters; in Upright Channel at 55 meters; near Pole Pass at 18 meters. A few were collected in Spring Pass at 55 meters; in Deer Harbor at 20 meters; off Point Caution at 55 meters; outside Brown Island at 91 to 110 meters; off Dinner Island at 18 to 27 meters; in West Sound at 13 meters.



Fig. 2. *Pagurus aleuticus* (Benedict).  $\times 1$ .

PAGURUS ALEUTICUS (Benedict). Fig. 2.

?*Pagurus streblonyx* Owen, Beechey's Voy., Zool., Crust., 1839. p. 81 (not Leach).

*Eupagurus aleuticus* Benedict, Proc. U. S. Nat. Mus. 15:3, 1892; Benedict, Proc. U. S. Nat. Mus. 23:460-463, text fig., 1901.

*Pagurus aleuticus* Holmes, Occas. Papers Calif. Acad. Sci. 7:136, 1900; Rathbun, Harriman Alaska Exped. 10:157, 1904.

**Characters.**—Very similar to *P. alaskensis*, but: the frontal teeth sharper; the eye stalks much stouter, somewhat longer; the antennal acicles broader at the base, exceeding the tip of the eyestalk by less than one-fourth its length; the carpus of the small cheliped three sided; the spines on the chelipeds more prominent. This species is most easily distinguished by the sulcus, deep at the base and becoming shallow at the end, which occupies the upper surface of the very wide, thin dactyls of the ambulatory legs.

*Color*.—Chelipeds and ambulatory legs light ochraceous-buff with mineral red above, shading to buff on the hands and dactyls.

*General Distribution*.—From Bering Sea (latitude of Probilof Islands) to Oregon, 14.6 to 435.3 meters (Rathbun).

*Local Distribution*.—Not as numerous as *P. alaskensis*. Found most commonly in Upright Channel at 46 to 55 meters. Also collected in West Sound at 37 meters; near Pole Pass at 18 meters; off Wasp Islands at 143 meters; in East Sound at 22 meters.



Fig. 3. *Pagurus ochotensis* (Brandt).  $\times 1$ .

PAGURUS OCHOTENSIS (Brandt). Fig. 3.

*Pagurus* (Eupagurus) *bernhardus* var. C, *spiniinana*; or sp. *ochotensis* Brandt in Middendorff, Reise in den äussersten Norden und osten Sibiriens, Bd. II, Zool. Th. I, p. 108, 1851; Stimpson, Proc. Acad. Nat. Sci. Phila. 269, 1851; Smithsonian Misc. Coll. pt. of Vol. 49, No. 1717, p. 218, 1907.

*Bernhardus armatus* Dana, U. S. Explor. Exped. Crust. 1:482, pl. 27, fig. 2, 1852.

*Eupagurus armatus* Stimpson, Boston Journ. Nat. Hist. 6: 484, 1857; Bate, Nat. in Brit. Columbia, 2:287, 1866; Whiteaves, Can. Nat. (2), 8:471, 1878.

*Pagurus ochotensis* Holmes, Occas. Papers Calif. Acad. Sci. 7:137, 1900; Benedict, Proc. U. S. Nat. Mus. 23:463, text fig., 1901; Rathbun, Harriman Alaska Exped. 10:157, 1904; Schmitt, Univ. of Calif. Pub. in Zool. 23:130, text fig. 84, 1921.

**Characters.**—Very similar to *P. alaskensis*, but: the frontal teeth more equal in prominence; the antennal acicle with the inner edge uneven, not spiny, exceeding the eye stalk by nearly half its length; chelipeds with the hand and carpus thickly set with slender spines; hands somewhat hairy but the hairs not reaching the tips of the spines; dactyls of the ambulatory legs nearly as long as the two preceding joints.

**Color.**—Pale olive buff to apricot orange with markings of madder brown similar to those of *P. alaskensis* but with wistaria violet largely replacing the opalescence.

**General Distribution.**—Unalaska to San Diego, California, 10.9 to 146.3 meters (Rathbun); Okhotsk Sea (Brandt); Japan (Stimpson, Balss).

**Local Distribution.**—Not as common as *P. alaskensis*. Found rather abundantly off Shaw Island at 91 to 128 meters; in Upright Channel at about 55 meters.



Fig. 4. *Pagurus hirsutiunculus* (Dana).  $\times 1$ .

## PAGURUS HIRSUTIUSCULUS (Dana). Fig. 4.

*Bernhardus hirsutiusculus* Dana, Proc. Acad. Nat. Sci. Phila. 5:70, 1851; Crust. U. S. Explor. Exped. pt. 1, p. 443, 1852, pl. 27, fig. 3, 1855.

*Eupagurus hirsutiusculus* Stimpson, Journ. Bost. Soc. Nat. Hist. 6:484, 1857; Proc. Acad. Nat. Sci. Phila. 237 and 249, 1858; Smithsonian Misc. Coll. pt. of Vol. 49; No. 1717, p. 223, 1907.

*Pagurus hirsutiusculus* Holmes, Occas. Papers Calif. Acad. Sci. 7:143, 1900; Rathbun, Harriman Alaska Exped. 10:159, 1904; Hilton, Journ. Ent. Zool. Pomona Coll. 8:63, 1916; Schmitt, Univ. of Calif. Pub. in Zool. 23:137, text fig. 91, pl. 16, fig. 4, 1921.

*Characters*.—Decidedly pubescent especially on the ambulatory legs, hand of the large cheliped often almost naked. Anterior portion of the carapace wider than long; median tooth acute, very distinct; lateral teeth lacking. Eye stalks short, thickset, usually exceeded by the antennal acicles. Chelipeds very unequal; granules on the upper surface of the large one distinct, separated; more sparingly granulated on the lower surface; hand nearly twice as long as wide; granules of carpus and merus sharper. Small cheliped with merus and carpus granulo-scabrous; hand small, somewhat flattened but with the sides rounded. Ambulatory legs granulo-scabrous, spined on lower surface of dactyls which are about the same length as the propodi.

*Color*.—Varies from light glaucous blue to olive which appears rather gray due to many short hairs; chelipeds drab grey with light glaucous blue granules, fingers white above and sometimes blue below; ambulatory legs having propodus white at distal end and chessylite blue at the proximal end; dactyls light glaucous blue striped longitudinally with Hessian brown. Antennae olive brown with golden yellow spots every two or three segments of the flagellum. The young differ so greatly from the adult in color that they may easily be taken for another species; chelipeds and walking legs vary from mahogany to blue black and in some cases are light olive, all are marked with white or very light blue at the articulations, the white at the distal end of the carpus of the small cheliped is often triangular; they may, however, be readily recognized by the antennae which even in the very young show the markings characteristic to this species.

*General Distribution*.—St. Paul Island, Pribilofs (T. Kincaid); Siberia, Kamchatka (Rathbun); Aleutian Islands to San Diego, California (Schmitt); Japan (Stimpson, Balss).  
Low tide to 31.1 meters (Schmitt).

*Local Distribution*.—The predominating species of hermits on most rocky shores at low tide. Found almost exclusively on the south



shore of Sucia Island although the specimens were for the most part very small. Very abundant at False Bay of San Juan Island; northeast end of Brown Island. Some were found on Minnesota Reef, these being for the most part in the tide pools on the southeast side. One was collected northeast of Brown Island at 27 to 37 meters.



Fig. 5. *Pagurus granosimanus* (Stimpson).  $\times 1$ .

*PAGURUS GRANOSIMANUS* (Stimpson). Fig. 5.

*Eupagurus granosimanus* Stimpson, Ann. Lyc. Nat. Hist. N. Y., 7:90, 1859 (1862); Smith, Rep. Prog. Geol. Sur. Canada, 1878-9, B. p. 211.

*Pagurus granosimanus* Holmes, Occas. Papers, Calif. Acad. Sci. 7:146, 1900; Rathbun, Harriman Alaska Exped. 10:160, pl. 5, fig. 8, 1904; Schmitt, Univ. of Calif. Pub. in Zool. 23:141, fig. 91, 1921.

**Characters.**—Anterior portion of carapace a little longer than wide, smooth; median tooth of front short, very blunt; lateral teeth rounded. Eye stalks rather stout, about two-thirds the length of the anterior portion of the carapace. Chelipeds very unequal, granulated on both upper and lower surfaces. Right cheliped not pubescent; two rounded blue tubercles on the lower surface of merus. Small cheliped very slightly pubescent; outer face of hand triangular, somewhat swollen, with edges rounded; upper margin of carpus armed with seven or fewer coarse spines. Ambulatory legs little if any longer than the chelipeds, sparsely hairy, with fine spines on upper edges and also on lower edges of dactyls.

**Color.**—Buffy olive to olive; chelipeds with large porcelain blue granules becoming a brighter blue near the extremities of the fingers especially on the under side of the hand; ambulatory legs with small blue spots from the front of which arise small tufts of setae; antennae apricot orange shading to olive in the basal segments. The young

are lighter in color and show very little if any blue, the granules and spots being almost white and the ambulatory legs tipped with orange.

*General Distribution.*—Unalaska to Escanada, Lower California. Beach to 27.4 meters (Rathbun).

*Local Distribution.*—Very common along rocky shores. Many were found under the rocks a little above mean low tide, also many moving about in the shallow water at the northeast end of Brown Island. Occasionally found to a depth of 27 meters.

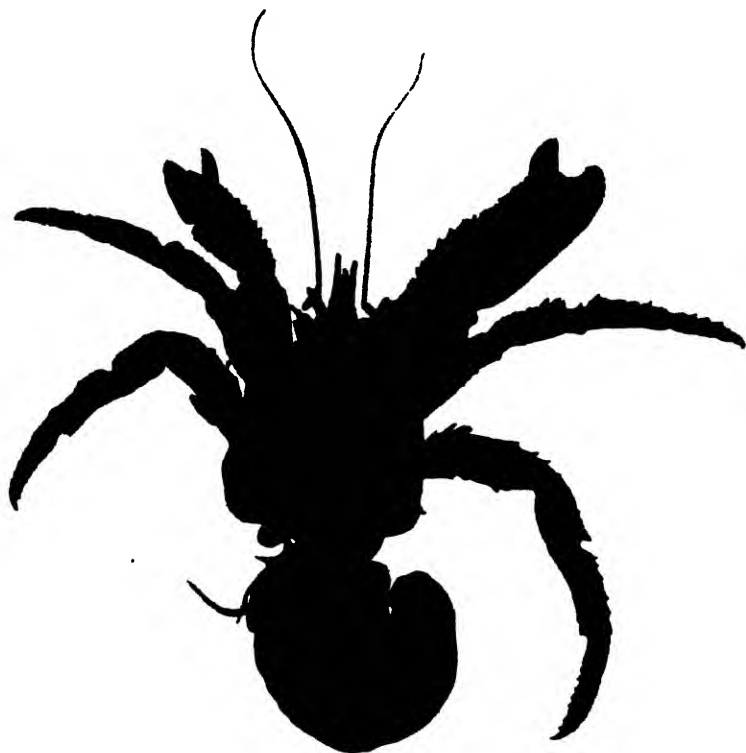


Fig. 6. *Pagurus beringanus* (Benedict).  $\times 1$ .

PAGURUS BERINGANUS (Benedict). Fig. 6.

*Eupagurus beringanus* Benedict, Proc. U. S. Nat. Mus. 15:17, 1892.

*Eupagurus newcombei* Benedict, Proc. U. S. Nat. Mus. 15:17, 1892.

*Pagurus beringanus* Rathbun, Harriman Alaska Exped. 10:159, pl. 5, fig. 5, 1904; Schmitt, Univ. of Calif. Pub. in Zool. 23:135, fig. 87, 1921.

*Characters.*—Somewhat pubescent particularly on the ambulatory legs and in older specimens on the carpus of the large cheliped.

Median tooth of front short and obtuse; lateral teeth rounded and not prominent. Anterior portion of carapace longer than wide. Eye stalks slender, about half the length of the anterior portion of the carapace. Chelipeds very unequal; upper surface of hand and carpus covered with spines and spiny granules. Large cheliped stout; upper margin of merus angular, with a patch of small sharp spines; lower surface pubescent, armed with two prominent orange tubercles; carpus oblong, about twice as long as wide; hand no wider and very little longer than carpus; fingers with small horny tips. Small cheliped armed with sharper spines especially on the upper edge of the carpus and the upper surface of the hand, outer surface of hand flat-triangular, forming a distinct angle or edge with the lower face which is quite smooth though hairy. Carpus and propodus of ambulatory legs armed above with spines; dactyls spinous below, slightly shorter than the propodi.

*Color*.—Brussels brown with brighter markings; chelipeds with flame scarlet spines, fingers pale glaucous green but tipped with scarlet, distal end of merus with a distinct scarlet band terminated by spines of the same color; ambulatory legs of a lighter hue than the chelipeds, often shading to the green on the propodi and dactyls, marked with large irregular spots of claret brown which are replaced by a spot of Brazil red at the articulations, dactyls tipped with claret brown and having spines of the same color. Antennae claret brown to Brussels brown. The young are lighter in color except the basal portion of the coxopodite which is a dark brown to olive and usually separated from the anterior portion of the segment by a darker brown band.

*General Distribution*.—Bering Sea (latitude of Nunivak) southward, along the Aleutian Islands and coast of Alaska to Monterey, California; 9.1 to 34.7 meters (Rathbun).

*Local Distribution*.—Rather common on most rocky shores at low tide and in tide pools. Found almost exclusively on the southeast side of Minnesota Reef; not so common on Brown Island as *P. hirsutiusculus* or *P. granosimanus*. A few were collected in West Sound at 11 meters; in Roche Harbor at 15 meters; between Point Caution and Brown Island at 24 meters; northeast of Brown Island at 64 meters; outside Fisherman's Bay at 82 meters.

*Remarks*.—*P. Newcombei* (Benedict) is included in *P. beringanus*, as it seems to be scarcely distinct. The species varies in the sharpness of the tubercles or spines of the chelipeds (Rathbun).



Fig. 7. *Pagurus brandti* (Benedict).  $\times 1$ .

PAGURUS BRANDTI (Benedict). Fig. 7.

*Eupagurus brandti* Benedict. Proc. U. S. Nat. Mus. 15:9, 1892.

*Pagurus brandti* Holmes, Occas. Papers Calif. Acad. Sci. 7:139, 1900. Rathbun, Harriman Alaska Exped. 10:157, pl. 4, fig. 4, 1904.

*Characters*.—Slightly pubescent but hair very fine and not conspicuous. Anterior portion of carapace slightly longer than wide, very convex; median tooth of front triangular, but little produced beyond the lateral teeth which are rounded and terminated by a submarginal spine. Eye stalks rather stout, slightly more than half as long as anterior portion of carapace. Antennal acicle extends a little beyond the eye. Large chelipeds stout, armed above with small, scattered, sharp spines; hand much swollen, about twice as long as wide, outer margin arcuate, inner almost a straight line; carpus about twice as long as wide. Small cheliped rather slender but extending beyond carpus of the large; carpus compressed and bicristate; hand with

oblique triangular face concave. Ambulatory legs rather slender, almost entirely unarmed except on upper and lower surfaces of dactyls which are wide, curved, and slightly twisted. This species is closely related to *P. dalli*.

*Color*.—Pinkish buff to pinkish cinnamon shading to madder brown at the articulations, ambulatory legs having the middle of the joints light.

*General Distribution*.—Bering Sea (latitude of Pribilof Islands) southward to Oregon; 16.5 to 221.3 meters (Rathbun).

*Local Distribution*.—Found quite abundantly off Wasp Islands at 128 to 143 meters. Rather common outside Fisherman's Bay at 76.8 meters; southwest of Shaw Island at 59 to 91 meters. Occasionally collected in West Sound at 13 to 18 meters; in Griffin Bay at 73 meters. *P. brandti* and *P. dalli* are usually collected together and commonly occupy sponges instead of shells.



Fig. 8. *Pagurus dalli* (Benedict.  $\times 0.7$ .



Fig. 9. *Pagurus dalli* (Benedict).  $\times 1$ .

**PAGURUS DALLI (Benedict). Figs. 8, 9.**

*Eupagurus dalli* Benedict, Proc. U. S. Nat. Mus. 15:9, 1892.

*Pagurus dalli* Holmes, Occas. Papers Calif. Acad. Sci. 7:139, 1900; Rathbun, Harriman Alaska Exped. 10:158, 1904.

**Characters.**—Very similar to *P. brandti* but: the anterior portion of the carapace is more nearly equal in width and length; median tooth of front produced farther beyond the lateral teeth; eye stalks smaller; chelipeds set with stronger spines; large cheliped having the carpus less than twice as long as wide and the hand more swollen; the dactyls of the ambulatory legs are more slender and not twisted.

**Color.**—Similar to *P. brandti* but having a sharply defined band of white near the distal end of the merus joints. This band of white is entirely wanting in *P. brandti* and separates the species at sight.

**General Distribution.**—Bering Sea (latitude of Nunivak) to Oregon; low water to 276.1 meters (Rathbun).

**Local Distribution.**—In general the same as that for *P. brandti* though usually more abundant.



Fig. 10. *Pagurus kennerlyi* (Stimpson).  $\times 0.94$ .

## PAGURUS KENNERLYI (Stimpson). Fig. 10.

*Eupagurus kennerlyi* Stimpson, Proc. Acad. Nat. Sci. Phila. p. 153, 1894; Benedict, Proc. U. S. Nat. Mus. 15:19, 1892; Walker, Trans. Liverpool Biol. Soc. 12:275, 1898.

*Pagurus kennerlyi* Holmes, Occas. Papers Calif. Acad. Sci. 7:143; Rathbun, Harriman Alaska Exped. 10:159, pl. 5, fig. 4, 1904.

*Characters.*—Pubescent, having scattered tufts of rather stiff hairs. Anterior portion of carapace a little longer than wide; median tooth of front triangular, lateral teeth rounded but armed with a strong submarginal spine. Eye stalks slender, about two-thirds the length of the anterior portion of the carapace. Antennal acicle reaching to about the tip of the eye. Chelipeds very unequal, set with strong spines. Merus of large cheliped nearly trihedral, lower margin spiny; carpus set on inner margin with 7 or 8 slender curved spines; hand a little wider than the carpus, traversed by seven rather irregular, longitudinal rows of slender spines, sparsely pubescent, the hairs reaching but little beyond the spine. Merus and carpus of small cheliped compressed, carpus having a double row of spines; hand with outer surface trigonal, set with spines. Ambulatory legs stout, dactyls not twisted.

*Color.*—Pale pinkish buff to pinkish cinnamon mottled with Hessian brown; spines on the hands white, hair brown tipped with cinnamon; ambulatory legs with less brown than the chelipeds. Upon casual observation the antennae appear annulated with the brown and white, but upon closer examination it is found that at about the middle of the flagellum the rings are made up of four to six brown segments followed in succession by one white, two brown, one white; then the series is repeated with the number of brown segments in the wider rings increasing to eight or nine towards the tip, and then being replaced entirely by white; in the basal portion the brown segments are fewer and many of the rings are incomplete; in the young the arrangement is less elaborate.

*General Distribution.*—Aleutian Islands to Washington; 16.5 meters to 177.4 meters (Rathbun).

*Local Distribution.*—Perhaps the most abundant deep water species represented. Collected in greatest numbers in Griffin Bay at 75 to 82 meters; off Wasp Island at 119 to 137 meters; off Shaw Island at 18 to 128 meters; in Upright Channel at 27 meters; both north and south of Flat Point at 40 to 51 meters. A few were collected off Minnesota Reef at 55 to 91 meters; off Dinner Island at 18 to 55



meters; northeast of Point Caution at 128 meters; off Point George at 124 meters; in Spring Pass at 40 meters; in Deer Harbor at 22 meters; in Fisherman's Bay at 3 meters; off Cattle Point at 27 meters.



Fig. 11. *Pagurus setosus* (Benedict).  $\times 1$ .

PAGURUS SETOSUS (Benedict). Fig. 11.

*Eupagurus setosus* Benedict, Proc. U. S. Nat. Mus. 15:19, 1892.

*Pagurus setosus* Rathbun, Harriman Alaska Exped. 10:159, pl. 5, fig. 1, 1904; Schmitt, Univ. of Calif. Pub. in Zool. 23:136, fig. 88, 1921.

*Characters*.—Very similar to *P. kennerlyi*, but: the median projection of front is rounded and a little in advance of the lateral projections, the eye stalks are somewhat shorter and stouter, the antennal acicle exceeds the eye stalk by almost one-fourth its length. The hands of both chelipeds are thickly set with hairs which are much longer than the sharp spines.

*Color*.—Pinkish buff with irregular bands of Hessian brown except on the hands and dactyls. Spines tipped with apricot orange. Hair brown at base and buff at the tip. Antennae brown on upper surface, buff below. The young are in general of lighter shades.

*General Distribution.*—From Kodiak, Alaska, to off Santa Cruz Island, California; 91.4 to 486.5 meters (Schmitt).

*Local Distribution.*—Not so abundant as *P. kennerlyi*. Rather common outside Indian Cove at 27 meters; in Upright Channel at 55 meters. A few were collected in West Sound at 37 meters; in Davis Bay at 9 to 18 meters.



Fig. 12. *Pagurus gilli* (Benedict).  $\times 1$ .

PAGURUS GILLI (Benedict). Figs. 12, 13.

*Eupagurus gilli* Benedict, Proc. U. S. Nat. Mus. 15:20, 1892.

*Pagurus gilli* Rathbun, Harriman Alaska Exped. 10:161, 1904.

*Characters.*—Anterior portion of carapace about equal in width and length, very smooth except for a few small pits; frontal teeth of about equal prominence. Eye stalks slender, about half as long as the anterior portion of the carapace. Antennal acicle does not exceed the tip of the eye. Chelipeds very unequal; merus of right cheliped short, trigonous; carpus broader than long, both margins produced into

thin, wing-like expansions, curved so that the inner surface is concave, upper surface rounding and smooth but inner margin slightly roughened, anterior margin set with small regular tubercles; hand smooth, more than twice as long as its greatest width, much narrower than the carpus. Small cheliped having the carpus elongated and flattened, the inner edge spiny; the hand much flattened, the edges upturned, the proximal edge overlapping the distal margin of the carpus. Ambulatory legs moderately stout; dactyls rather wide, inner surface concave and spinulose.

The young differ markedly from the adult specimens in that: the carpus of the large cheliped lacks almost entirely the thin wing-like expansions; the hand is slightly wider than the carpus; they may however be identified by the characteristically flattened hand of the left cheliped.

*Color.*—Orange chrome to grenadine red, fingers and outer margin of large hand outlined with white and having small white pits which are also present on the fingers of the small hand and on the first three joints of the ambulatory legs.

*General Distribution.*—Bering Island, Aleutian Islands; Alaska Peninsula southward to Revillagigedo Island, southeastern Alaska; low water to 109.7 meters (Rathbun).

*Local Distribution.*—Only two mature specimens were found, a male in Griffin Bay at a depth of 55 to 64 meters; a female in Davis Bay at a depth of about 1 meter. Two young were found, one at low tide off Minnesota Reef, the other at about 1 meter off the San Juan Islands but the exact location is not known.



Fig. 13. *Pagurus gilli* (Benedict), young.  $\times 1$ .



Fig. 14. *Pagurus tenuimanus* (Dana).  $\times 1$ .

**PAGURUS TENUIMANUS (Dana). Fig. 14.**

*Bernhardus tenuimanus* Dana, Proc. Acad. Nat. Sci. Phila. p. 269, 1851; Crust. U. S. Exped. pt. 1, p. 447, pl. 27, fig. 7, 1852.

*Eupagurus tenuimanus* Stimpson, Journ. Bost. Soc. Nat. Hist. 6:483, 1857; Proc. Nat. Sci. Phila. 237, 1858; Smith, Rep. Prog. Geol. Sur. Canada, B. P. 211, 1878-9; Benedict, Proc. U. S. Nat. Mus. 15; 1, 1892; Walker, Trans. Liverpool Biol. Soc. 12:274, 1898.

*Pagurus tenuimanus* Holmes, Occas. Papers, Calif. Acad. Sci. 7:148, 1900; Rathbun, Harriman Alaska Exped. 10:160, 1904.

**Characters.**—Carapace smooth; anterior portion about as long as wide; median tooth of front but little more prominent than the lateral teeth which end in a minute spine. Eye stalks stout, about half as long as the anterior portion of the carapace. Antennae rather heavy, long. Chelipeds granulated and tuberculated, very unequal; small hand little more than one fourth the greatest width of the large hand. Large cheliped with merus trigonous, more or less tuberculated, supero-distal angle furnished with several marginal spines; carpus stout, a little longer than wide, the upper surface decidedly convex and thickly set with strong tubercles, inner edge with a row of stout spines; hand very wide, suborbicular, the edges produced into prominent thin expansions, both surfaces thickly covered with small tubercles; fingers somewhat flattened and hollowed out above. Small cheliped with merus flattened; carpus compressed, inner edge spinous, hand flattened but with raised edges. Ambulatory legs nearly naked, upper margins spinulous, dactyls slightly twisted.

**Color.**—Brilliantly colored; light pinkish cinnamon to natal brown with maroon orange, chrome, and grayish violaceous blue markings. Chelipeds natal brown to blue with chrome at both the proximal and distal ends, spines white; carpus natal brown tinged with maroon, tubercles white tipped; hand cinnamon. Ambulatory legs with merus similar to that of the chelipeds; first three segments from the distal end pale olive buff to chrome spotted and streaked longitudinally with maroon. Flagellum of antennae cinnamon with a maroon line extending the full length of both the outer and inner surfaces.

**General Distribution.**—From Aleutian Islands and Alaska Peninsula to Strait of Fuca and Puget Sound; beach to 224.9 meters (Rathbun).

**Local Distribution.**—Common. Found in greatest number off Shaw Island at 18 to 128 meters; in Griffin Bay near Cattle Point at 77 meters; off Wasp Islands at 143 meters; off Point Caution at 4 to 55 meters. Collected also in Upright Channel off Flat Point at 37 to 73 meters; northeast of Canoe Island at 18 to 37 meters. A very few were collected in West Sound at 37 meters; off Minnesota Reef at 1 to 91 meters; off Dinner Island at 46 to 55 meters; in False Bay at 1 meter; in Kanaka Bay at 1 meter; in Fisherman's Bay at 4 to 7 meters; a few small specimens in Davis Bay at 9 to 18 meters.



Fig. 15. *Pagurus splendescens* Owens.  $\times 1$ .

PAGURUS SPLENDESCENS (Owen). Figs. 15, 16.

*Pagurus splendescens* Owen, Zool. Beechey's Voyage, p. 81-82, pl. 25, figs. 1 and 1a, 1839; Holmes, Occas. Papers Calif. Acad. Sci. 7:234, 1900; Rathbun, Harriman Alaska Exped. 10:161, 1904.

*Eupagurus splendescens* Calman, Ann. N. Y. Acad. Sci. Vol. XI, No. 13, p. 260, 1898.

*Characters.*—This unusual species has the carapace short, broad, granulated, much harder than in most; anterior portion heart-shaped; frontal tooth long, reaching to about the middle of the short, stout eye stalks, with smaller dentations behind the lateral teeth; anterior lateral angles of the branchial regions projecting forward in a prominent process. Chelipeds elongated, compressed, very unequal, granulated below, set above with longitudinal rows of small tubercles; fingers especially of the small chela very long and slender, closing with a very firm grasp with no intervening space. Ambulatory legs decidedly longer than the chelipeds, with rows of very small tubercles; dactyls very slender, twisted; antennae slender, longer than the chelipeds; acicles acute, greatly exceeding the eye stalks in length. Abdomen shorter in proportion to the body than in most of this genus; the pleopods of the female four in number as is usual in this genus, but entirely lacking in the male which ordinarily possesses three.

**Color.**—Light vinaceous cinnamon to light mauve, iridescent, having a metallic lustre and reflecting hues of pink, lavender, green and gold; tubercles dark; under side of chelipeds and walking legs pale pinkish buff to pale mauve, fingers deep lavender tipped with white; inner surface of antennules bronze to gold.

**General Distribution.**—From Point Barrow, Alaska, through Bering Sea to Kamchatka and Washington; below low water to 411.5 meters (Rathbun).

**Local Distribution.**—Found rather abundantly off Shaw Island and in Upright Channel at 22 to 55 meters; south of Flat Point at 40 to 49 meters. A few were collected off Canoe Island at 27 to 33 meters; in Griffin Bay at 77 meters; in Spring Pass at 33 meters; off Point Caution at 37 meters; northeast of Brown Island at 70 meters; off Cattle Point at 37 meters.



Fig. 16. *Pagurus splendescens* Owens, in partly disintegrated shell.  $\times 1$ .

#### Genus PYLOPAGURUS Milne-Edwards & Bouvier

Abdomen with paired appendages, other than the uropods, on the first abdominal segment in the female only. External maxillipeds widely separated at base; exopodites of all three pairs of maxillipeds flagellate. Chelipeds dissimilar and unequal, the right vastly the

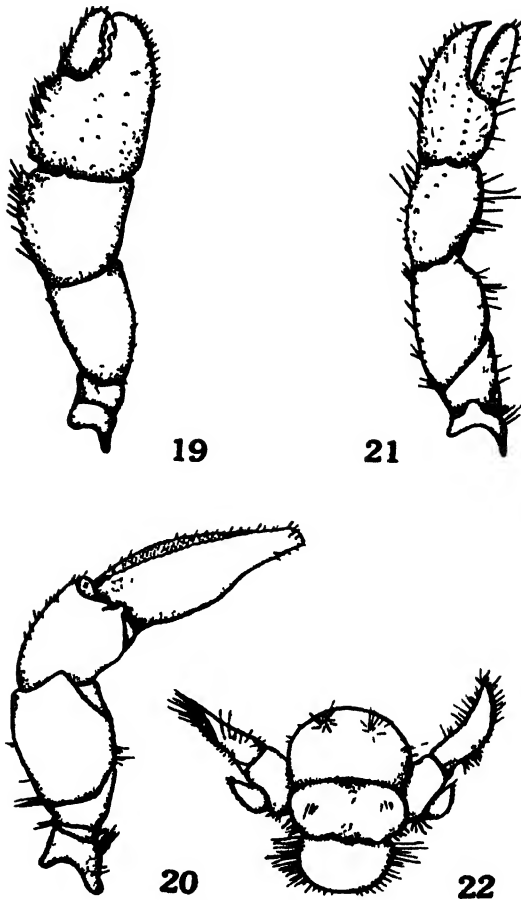
larger. Large hand more or less operculiform; greater part of upper surface transversely concave, trough-shaped or discoidal with raised margins, bent at an angle to the wrist. Fourth pair of legs subchelate.



Fig. 17 (above). *Pylopagurus schmitti*, out of worm-tube.  $\times 1$ .

Fig. 18 (below). *Pylopagurus schmitti*, in worm-tube.  $\times 1$ .





*Pylopagurus schmitti* n. sp

Fig. 19. Right cheliped, dorsal.  $\times 6$ .

Fig. 20. Right cheliped, lateral.  $\times 6$ .

Fig. 21. Left cheliped, dorsal.  $\times 6$ .

Fig. 22. Telson, uropods and last abdominal segment.  $\times 6$ .

***Pylopagurus schmitti*, new species. Figs. 17-22.**

*Characters*.—Somewhat pubescent, particularly on the chelipeds. Anterior portion of carapace little longer than wide; median tooth of front triangular, acute, prominent; lateral teeth practically obsolete. Eye stalks stout at the base but rather tapering, about two thirds the length of the anterior portion of the carapace. Antennal acicle not

reaching the tip of the eye. Large cheliped with merus compressed; carpus distally widened, upper surface rounded and armed particularly along the inner surface with spines which incline forward; hand oblong, of nearly uniform width; inner margin of palm armed with spines similar to those of the carpus; upper surface slightly convex but appearing quite flattened; fixed finger broad, its outer edge armed with small anteriorly inclined spines; movable finger more nearly uniform in width. Small cheliped rather stout, nearly as long as the large; hand somewhat flattened; fingers about the same length as the palm. Ambulatory legs rather slender, laterally compressed, pubescent; dactyls slender, curved, decidedly tapering from the base, spiny below, about the same length as the propodi. Both the telson and the uropods very nearly symmetrical.

*Color*.—Pale pinkish buff to white with irregular spots and bands of orange cinnamon; the fingers being tipped with apricot orange; the fingers of the large hand are armed on the inner margins with large white tubercular teeth; the antennae orange vinaceous.

*Local Distribution*.—Not uncommon. Rather numerous off Point Caution at 22 to 37 meters; in Griffin Bay near Cattle Point at 77 meters. Collected also both north and south of Flat Point at 40 to 51 meters. Found in worm tubes.

*Remarks*.—The type, a male, taken at about 37 meters off Point Caution, measures 34 mm long and is deposited with the Division of Marine Invertebrates of the Smithsonian Institution. A specimen of *Pylopagurus minimus* from Monterey Bay, California, loaned by the Division of Invertebrates of the Smithsonian Institution was examined. *P. minimus* has the large hand distally widened, while that of *P. schmitti* is more nearly uniform in width and appears flattened; the movable finger in *P. schmitti* is also more uniform in width. The lateral teeth of *P. minimus* are rounded while in *P. schmitti* they are practically obsolete.

#### Genus PAGURISTES Dana

Chelipeds similar, equal, subequal or one (usually the left) may be larger than the other. Fourth pair of legs simple. External maxillipeds approximated at base. Abdomen with paired appendages other than the uropods on the first two segments in the male and the first segment of the female.



Fig. 23. *Paguristes turgidus* (Stimpson), male.  $\times 0.6$ .

**PAGURISTES TURGIDUS (Stimpson). Figs. 23, 24.**

*Empagurus turgidus* Stimpson, Proc. Bost. Soc. Nat. Hist. 6:86, 1857.

*Clibanarius turgidus* Stimpson, Journ. Bost. Soc. Nat. Hist. 6:484, pl. 21, fig. 1, 1857; Bate in Lord's Nat. in Vancouver's Is., 2:276, 1866; Whiteaves, Can. Nat. (2), 8:471, 1878.

*Paguristes turgidus* Stimpson, Proc. Acad. Nat. Sci. Phila. 236, 1858; Ann. N. Y. Lyc. Nat. Hist. 7:86, 1860; Smith, Rep. Prog. Geol. Sur. Canada, B, 211, 1878-9; Walker, Rep. Trans. Liverpool Biol. Soc. 12:275, 1898; Holmes, Occas. Papers Calif. Acad. Sci. 7:151, 1900; Rathbun, Harriman Alaska Exped. 10:161, 1904; Schmitt, Univ. of Calif. Pub. in Zool., 23:123, pl. 18, figs. 1 and 8, 1921.

**Characters.**—Decidedly hirsute. Anterior portion of carapace longer than wide; teeth of front subequal, rather prominent. Eye stalks slender, nearly half the length of the anterior portion of the carapace. Antennal flagella short, sparsely hairy. Chelipeds similar, upper surface set with dark tipped spines; distal portion of inner margin of movable finger and pollex dark, serrate; proximal portion armed with four conical teeth. Ambulatory legs rather stout; dactyls slightly longer than propodi.

**Color.**—Pinkish buff to vinaceous-rufous (brown), obscured by the hirsute covering; eye stalks, antennules and inner surface of flagella with a longitudinal streak of vinaceous-rufous; spines dark tipped.

**General Distribution.**—From British Columbia to San Diego, California; to a depth of 464.5 meters (Schmitt).

**Local Distribution.**—Rather common in deep water. Found in greatest numbers northeast of Canoe Island at 27 to 37 meters; off Point George at 113 meters; off Flat Point at 20 to 42 meters; in Upright Channel at 46 to 55 meters. Also collected outside Brown Island at 91 to 110 meters; off Point Caution at 37 meters; between Turn Island and San Juan Island at 25 to 55 meters.



Fig. 24. *Paguristes turgidus* (Stimpson), female.  $\times 1$ .

## PLATE 34

**Fig. 25.** *Pagurus alaskensis* (Benedict), male, dorsal view. <

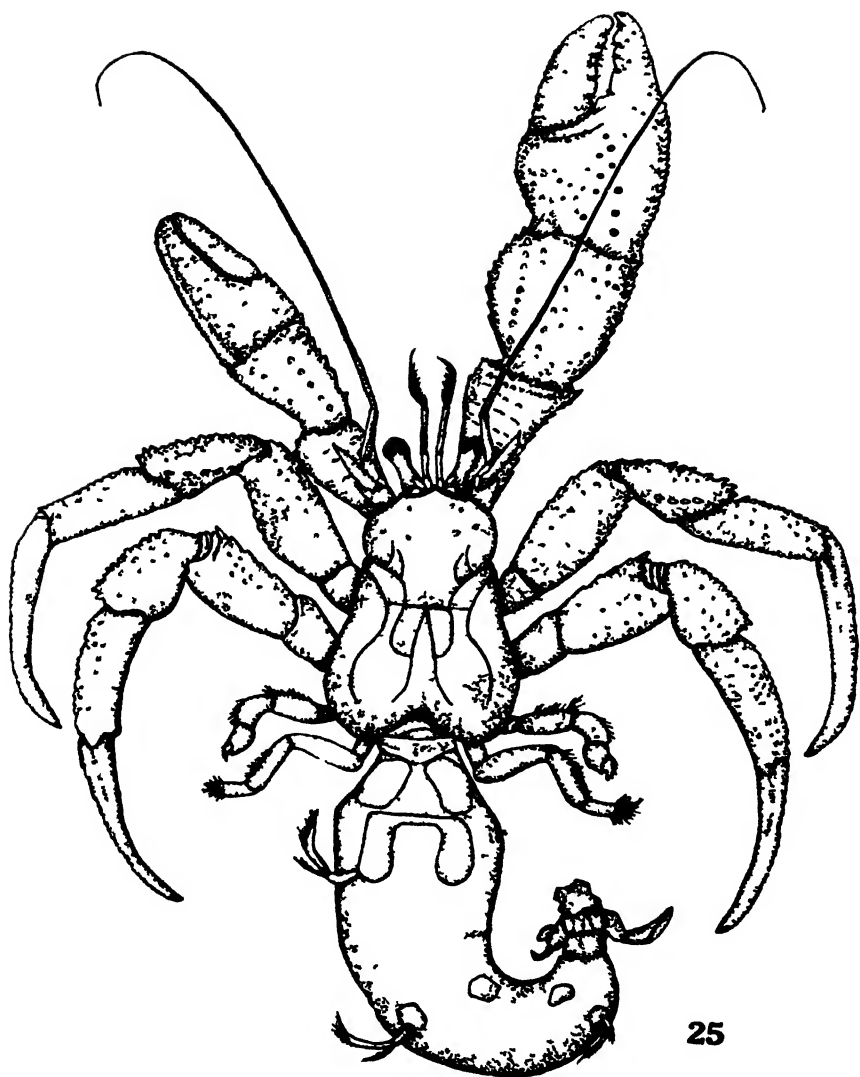


PLATE 34

## PLATE 35

bp = Basipodite  
cp = Carpopodite  
cx = Coxopodite  
dp = Dactylopodite  
en = Endopodite  
ep = Epipodite  
ex = Exopodite

fl = Flagellum  
ip = Ischiopodite  
mp = Meropodite  
pp = Propodite  
pt = Potopodite  
sc = Scaphognathite

*Pagurus alaskensis* (Benedict) ; drawings  $\times 3$ .

- Fig. 26. Left first antenna (antennule), lateral.  
Fig. 27. Left second antenna, dorsal.  
Fig. 28. Left mandible, ventral.  
Fig. 29. Left first maxilla, ventral.  
Fig. 30. Left second maxilla and scaphognathite, ventral.  
Fig. 31. Left first maxilliped, ventral.  
Fig. 32. Left second maxilliped, lateral.  
Fig. 33. Left third maxilliped, lateral.

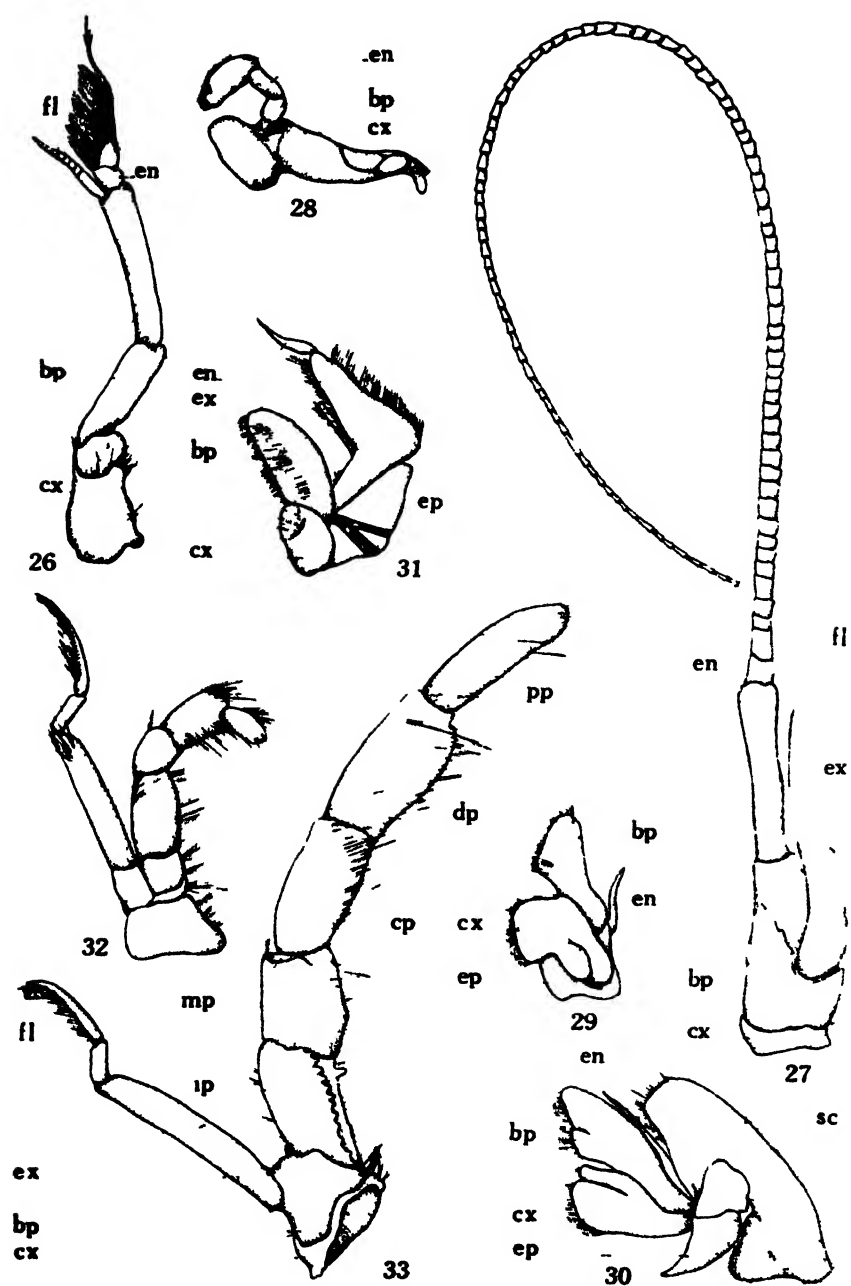


PLATE 35



## PLATE 36

bp = Basipodite  
cp = Carpopodite  
cx = Coxopodite  
dp = Dactylopodite  
en = Endopodite  
ep = Epipodite  
ex = Exopodite

fl = Flagellum  
ip = Ischiopodite  
mp = Meropodite  
pp = Propodite  
pt = Protopodite  
sc = Scaphognathite

*Pagurus alaskensis* (Benedict)

- Fig. 34. Right cheliped, dorsal.  $\times 1$ .  
Fig. 35. Left cheliped, dorsal.  $\times 1$ .  
Fig. 36. Left third pereopod (ambulatory leg), lateral.  $\times 1$ .  
Fig. 37. Left fourth pereopod, dorsal.  $\times 3$ .  
Fig. 38. Left fifth pereopod, dorsal.  $\times 3$ .  
Fig. 39. First pleopod of female, dorsal.  $\times 3$ .  
Fig. 40. First pleopod of male, dorsal.  $\times 3$ .  
Fig. 41. Telson, uropods and last abdominal segment.  $\times 3$ .

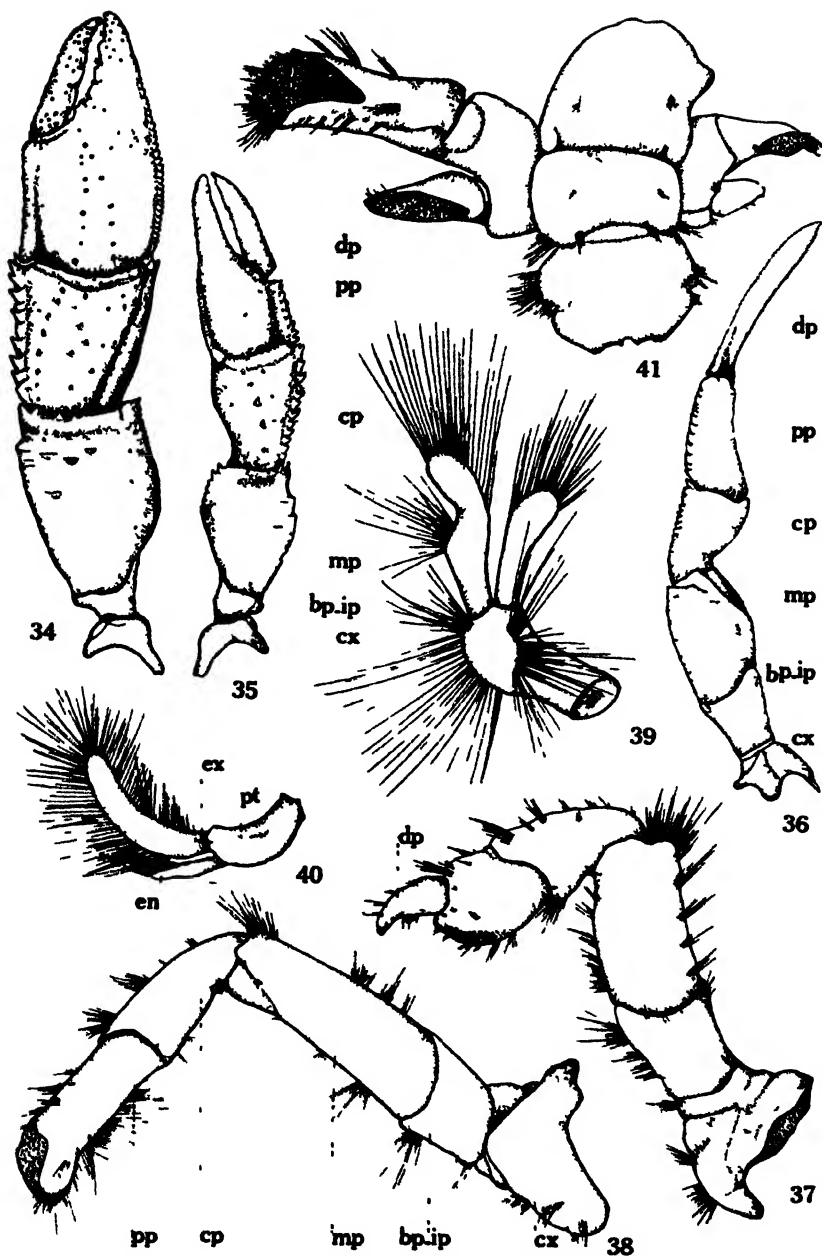


PLATE 36

## GLOSSARY

- Acicle: A scale.
- Ambulatory: Used for walking.
- Annulated: Ringed.
- Antenna: One of the paired, lateral, movable, jointed appendages of the cephalothorax of a crustacean.
- Antennule: One of the anterior and usually smaller pair of antennae of a crustacean.
- Anterior: Near or towards the head.
- Approximated: Very nearly together.
- Articulation: A joint.
- Basipodite: Second segment from the base of a typical appendage of a crustacean.
- Bicristate: Having two crests or ridges.
- Carapace: The chitinous shield covering the cephalothorax of a crustacean.
- Carpal: Pertaining to the wrist or carpus.
- Carpopodite: Carpus.
- Carpus: The wrist; fifth segment from the base of a typical appendage of a crustacean.
- Cephalothorax: The anterior division of the body of a crustacean.
- Chelate: Having a chela or pincer-like claw.
- Cheliped: A prehensile or chelate appendage of a crustacean.
- Conical: Round and tapering to a point.
- Coxopodite: The segment of a typical crustacean appendage that articulates with the body.
- Dactyl: Last segment of a typical crustacean appendage; the claw.
- Dactylopodite: The movable claw of a cheliped.
- Dentation: An angular tooth-like projection.
- Discoidal: Disk-shaped.
- Distal: Farthest from the body.
- Endopodite: The inner branch of a typical appendage of a crustacean. It is variously modified, being the ambulatory leg in decapods.
- Epipodite: A branch of the basal segment of the protopodite of the thoracic limbs of many crustaceans often extending into gill chambers and serving to keep the gills apart.
- Exopodite: The outer of the two branches of a typical appendage of a crustacean.
- Flagellate: Having flagella.
- Flagellum: A whip-like appendage.
- Glabrous: Smooth, without hairs or projections.
- Granulate: Having numerous small elevations on the surface.
- Granulo-scabrous: Roughened by granules.
- Hirsute: Covered with coarse hairs or hair-like projections.
- Ischopodite: Basal segment of the endopodite; third segment from the base of a typical appendage of a crustacean.
- Mandible: A jaw.
- Manus: A hand.
- Maxilla: One of the two pairs of appendages immediately behind the mandibles of a crustacean.
- Maxilliped: One of the three pairs of appendages next behind the maxillae of a crustacean.

- Meropodite:** The fourth segment from the base of a typical appendage of a crustacean.
- Merus:** The meropodite.
- Obsolete:** Indistinct.
- Operculiform:** Lid-like.
- Pereiopod:** A thoracic appendage of a crustacean.
- Pleopod:** An abdominal appendage of a crustacean.
- Posterior:** At or towards the hinder end of the body.
- Prehensile:** Adapted for grasping.
- Propodite:** The sixth segment from the base of an endopodite.
- Propodus:** The palm or propodite.
- Protopodite:** The coxopodite together with the basipodite.
- Proximal:** Near or toward the body; opposed to distal.
- Pubescent:** Covered with short hairs or down.
- Scaphognathite:** An appendage of the second maxilla of a decapod crustacean which serves by its constant motion to force the water out of the gill cavity after it has aerated the gills.
- Segment:** The portion of an appendage between two joints.
- Seta:** Any slender, more or less rigid, bristle-like structure.
- Spinous:** Having spines.
- Spinulous:** Having small spines.
- Sub-chelate:** Imperfectly chelate; ending in a sub-chela, a terminal hook-like appendage that bends down on the segment to which it is attached.
- Sub-equal:** Almost equal.
- Sub-marginal:** Situated near the margin.
- Sulcus:** A groove.
- Supero-distal:** Upper and farthest from the body.
- Telson:** The last segment of the abdomen of a crustacean.
- Trigonal:** Three-cornered, triangular.
- Trihedral:** Having three intersecting surfaces as sides.
- Tubercle:** A small knob-like prominence or excrescence.
- Tuberculate:** Having tubercles.
- Uropod:** Any of the abdominal appendages of a crustacean or other arthropod, especially one of the posterior ones when larger than the rest or different in structure.



# **Some Physiology of the Sieve Tubes of *Nereocystis***

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The data on bladder kelp reported in this paper bear mainly on the extent to which its sieve tubes function in translocation, and the question of what classes of substances they carry. The fact that the sieve tubes of the stipe of this plant are in the form of a pith web on the inner surface of the wall of a cavity makes it particularly adaptable to such an investigation.

The work was done at the Puget Sound Biological Station at Friday Harbor, Washington, between June 15 and July 30, 1919.

## **PLANT**

This plant, as is well known, is marine and consists of a slender rope-like stipe attached by a powerful holdfast and enlarging upward into a hollow pneumatocyst on which are borne the slender ribbon-like fronds, (MacMillan 1899, Frye 1906, Setchell 1908, Rigg 1912). The whole plant is commonly 10 to 20 meters in length, sometimes reaching as great a length as 38 meters (Frye, Rigg & Crandall 1915). The fronds lie at the surface of the water. They are thin and leaf-like. In mature plants they sometimes reach a length of 7.8 meters and a width of 20 cm, though they are commonly shorter and narrower than this.

The pneumatocyst is commonly 2 meters or more in length, the greatest length reported being 4.62 meters. It is terminated by a bulb commonly 8 cm or more in diameter, the greatest diameter reported being 13.7 cm (Frye, Rigg & Crandall 1915). The cavity of the pneumatocyst has a capacity of 4 liters or less (Zeller & Neikirk 1915). The composition of the gas in it is somewhat similar to that of air, so far as the content of oxygen and nitrogen are concerned. It has been shown (Langdon 1916) to contain 0.4% to 12.2% of carbon monoxide and usually to be free from carbon dioxide. Langdon and Gailey (1920) have taken the view that the presence of carbon monoxide is connected with respiration. The gas pressure within the cavity is considerably less than one atmosphere (Frye 1916). The chlorophyll of this plant is like that of higher plants (Howard 1921).

## **MATERIAL**

The inner surface of the pneumatocyst is covered with a somewhat cobweb-like mass of filaments (Fig. 1) most of which extend

lengthwise of the plant. The course of these filaments is from the fronds, which lie at or near the surface of the water, to those portions of the plant which lie farther beneath the water. Not all of these filaments, however, extend lengthwise of the plant; some of them extend nearly or quite at a right angle to the longitudinal ones. A few even leave the surface and extend directly across the cavity.

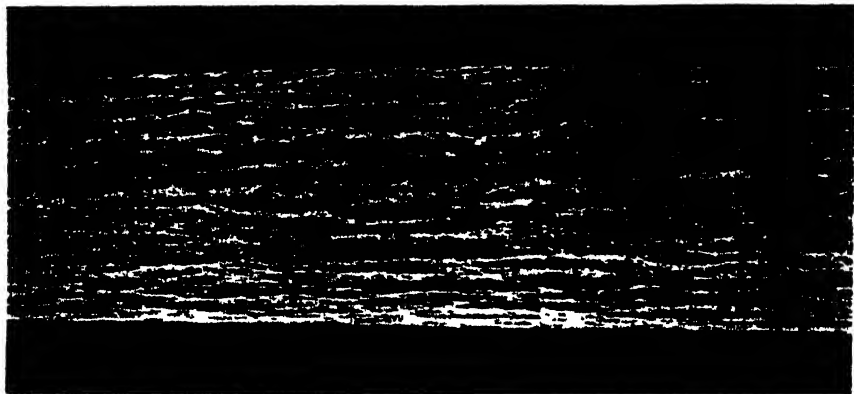


FIG. 1. Inner surface of a pneumatocyst showing the pith web. The pneumatocyst was split, the dark lines at the sides are the cut surfaces of the wall. Photograph by C. M. Child.  $\times 1$ .

On cutting the bulb in two lengthwise through the base of a frond, the medulla of the frond can be readily traced, even with the unaided eye, through the pneumatocyst wall to its inner surface (Fig. 2). The growth of pith web is much more dense where this medulla comes to the inner surface of the pneumatocyst wall. It is readily seen with the unaided eye that the filaments composing the pith web radiate from this mat, extending over the inside of the bulb and thence directly down the inner wall of the tube-like portion of the pneumatocyst. The layer of pith web is decidedly thin on the wall of the bulb and is much thicker on the wall of the tube, which is narrower than the bulb. The layer gets gradually thicker and denser toward the lower portion of the pneumatocyst as the tube becomes narrower. These facts suggest that the distribution of the pith web as the plant matures is correlated with translocation rather than with anything relating to the surface on which it lies, and from which it may have originated.

The work reported in this paper consists in (1) a microscopic examination of these filaments, (2) macrochemical tests, mainly for proteins, made on water extracts from the pith web, and (3) micro-

chemical tests on the walls and contents of the filaments composing the pith web.

It was found that by making two parallel transverse cuts across the pith web at a distance of two or three centimeters from each other, the filaments between the two cuts could be readily pushed together with a dull knife, and the cord-like mass of filaments lifted out with a pair of forceps. Such a mass of fibers was much shorter than before it was cut and loosened from the pneumatocyst wall. The contraction was often as much as 15%.

The investigation was confined to the pith web. No work was done on the sieve tubes in the fronds. No sections of any material were made. The filaments were mounted whole except where broken or partly disintegrated by mechanical treatment, or by the reagents used as indicated in the text and the figures. All material was fresh, no preserved material being used in any case. The time elapsing between the removal of the kelps from the water and the examination or treatment of the material varied from a few minutes to 12 hours. About 60 different plants in all were examined. These were collected at various times of day and at various places, all within a radius of 2 miles from the Biological Station.

#### MICROSCOPIC EXAMINATION

Under the microscope it was seen that the filaments making up the pith web in this kelp are of several kinds (Figs. 3, 11, 14, 16). They vary in both size and structure. All of the filaments seen are one cell in width and have cross walls (Figs. 4, 14, 16). In most filaments the end walls of the cells show a striking resemblance to the sieve tubes of higher plants. Perforations are plainly seen, and the plate is thicker at the margin than in the middle.

These tubes having sieve plates vary a good deal in size. The length of those measured was from 0.35 to 3 mm. In width they were found to vary from 17 to 54 microns. There is much more uniformity in the width of the sieve plates than there is in the width of the cells at any point except their ends. The sieve plates, of course, form the ends of the cells.

Cells that are short or of medium length are usually of the same width throughout, this width being, of course, the diameter of the sieve plate. The plates in such cells may be either small or large. Cells that are very long are much narrower in the middle than at the ends, where the sieve plate makes the width permanent.

The tubes branch, the branches being usually narrower than the



tubes from which they come. Branches are commonly traceable from one longitudinal tube to another (Fig. 14), many of them connecting wide tubes with narrow ones.

Large accumulations of colorless, highly refractive material against the sieve plates were found. These are usually somewhat cone-shaped (Fig. 5) and are frequently as much as 0.6 mm long. Such accumulations of material have been called callus by other workers on this and other kelps (Sykes 1908, and the papers there cited), and by some workers on seed plants (Hill 1903). Haberlandt (1914, p. 331) speaks of them as "plugs" in higher plants.

These callus masses are usually clearly distinguishable bodies with definite boundaries. Some of them, however, merge gradually with the protoplasm. In some cases the callus forms a mass around the protoplasm at the sieve plate, the protoplasm extending through this mass to the sieve plate (Figs. 7, 10). In some cases the callus mass, unchanged in form, slipped out of the end of the cell when the sieve plate was destroyed (Fig. 13), while in other cases the material composing it flowed out of the cell (Fig. 12).

The callus masses are common in the long tubes whose middle portion is narrower than the sieve plates. Such tubes have been called "trumpet hyphae" by Oliver (1887) and other workers. The calluses are rare and imperfect in the wider, shorter tubes. They frequently occur in pairs, one on each side of a sieve plate (Fig. 6). Sometimes the two members of a pair are equal, but frequently one is much larger than the other (Fig. 9). Frequently the large ones are found on the same side of the sieve plate in several consecutive cells. In a few cases a large one was found on one side of a plate and none on the other. They do not seem to be connected in any way with the side wall of the cell.

In many cases the cells were collapsed, looking flat and ribbon-like. In a few cases they were somewhat twisted. The walls commonly have short slit-like markings extending crosswise of the cells. These seem to be wrinkles due to the contraction of the cells when they are loosed from the pneumatocyst wall.

In kelps whose stipes have grown in spiral form instead of straight, such as have been described by the writer (1917), the tubes follow the spirals. In kelps whose pneumatocysts have suffered injury on the external surface either mechanically or as a result of the activity of organisms, the pith web is frequently absent opposite the injury, or at least shows a tendency to degenerate, though elsewhere than opposite the injury it appears healthy.

In some filaments the end walls do not show the sieve plate-like modifications. The cells of such filaments are of practically the same width throughout, and are shorter than cells of the same width having sieve plates. No accumulation of callus was seen in such cells. Filaments of this sort with free ends are common (Fig. 10).

The data here presented are consistent with the view taken by other workers (Sykes 1908, and the literature there cited) that these sieve tubes are comparable in structure and formation with the sieve tubes of seed plants.

The data suggest that the older sieve tubes have been much stretched by the rapid elongation of the stipe and that they gradually become functionless as their age increases, the accumulation of callus being correlated with the loss of function as indicated by the work of Oliver (1887). The considerable contraction and wrinkling of the tubes on being freed from the pneumatocyst wall tends to confirm the view taken by MacMillan (1899) that they have been stretched by rapid growth. The position of the callus masses suggests that they are connected with a movement of materials in one direction in the tubes.

The fact that long narrow tubes showing callus masses are connected by cross tubes with shorter, wider tubes showing no callus masses, suggests transfer of materials from old tubes which are becoming functionless to younger tubes whose function of translocation is more active.

The data are consistent with the view commonly taken that the pith web originates from the inner surface of the pneumatocyst, but is distributed by rapid growth so that it is less uniform as the kelp matures.

#### MACROCHEMICAL TESTS

Several protein tests were applied as directed by Hawk (1918). Masses of sieve tubes prepared as stated above were used. Microscopic examination of such material indicated that very few cells of the pneumatocyst wall were included. Material as removed from the kelps was transferred to a small amount of distilled water in a Syracuse watch glass until the glass was practically full. Extracts from such masses of material were then made in two ways. (a) A watch glass of material was extracted a few hours with cold distilled water and filtered through filter paper, about 30 cc of filtrate being secured from each glass of material. (b) Other material was boiled 15 to 30 minutes in distilled water in a beaker and then filtered, the mass of material and the volume of filtrate being approximately the same as

in (a). Tests were in all cases performed in test tubes, approximately 3 cc of the filtrate being used. All of the tests here reported were made on at least six different lots of material, each lot being from a different kelp. The kelps used were collected at different times of day at different places in the vicinity of the Puget Sound Biological Station. The reagents used were in every case tested on fresh raw egg albumen as directed by Hawk (1918, p. 96). Wherever it seemed desirable, controls were also run by adding the reagents to distilled water instead of to the extract.

In the following statement of results (a) and (b) indicate respectively the filtrates prepared as described above:

1. Millon's reagent. (a) Dense white precipitate becoming slate colored at top on boiling but again colorless and finally fibrous on further boiling (only a few seconds in all). In some cases a *very* slight pink color on standing 24 hours. (b) Dense white precipitate resembling white of egg in appearance. Pink color always evident after brief boiling, sometimes on standing a few minutes, sometimes only at the end of 24 hours. Control with egg albumen gave white precipitate remaining white after boiling, but becoming red on standing over night. Precipitate became slate colored if very concentrated material was used.

2. Xanthoproteic test. (a) No precipitate while cold, but considerable white precipitate on heating. Precipitate stringy in some cases. Always dissolved, sometimes on adding ammonia, sometimes before. Yellow color always evident on adding ammonia, but no orange color. (b) White precipitate at once, increasing with boiling, and turning yellow with ammonia, but no orange color. Control with egg albumen gave a white precipitate which turned yellow on heating but did not dissolve at once. On cooling and adding ammonia, it turned orange and dissolved after several hours.

3. Biuret test. (a) Coagulated mass formed and suspended in the liquid on adding reagents. Red-violet color evident in coagulum at once in some cases. Also in liquid after standing a few hours. In other cases the color was blue only. (b) Blue precipitate in most cases, sometimes slightly violet. The control with egg albumen gave a purplish-violet color. The reagents added to distilled water gave no perceptible color.

4. Ring biuret. (a) No color at once, but slight violet color at junction on standing 24 hours. (b) Test not applied. Control with egg albumen gave a pinkish-violet color at the junction.

5. Picric acid. (a) Yellow precipitate either at once or on

standing. Sometimes dissolved on standing several hours, sometimes not. (b) Yellow precipitate appearing as needle-shaped particles. Control with egg albumen gave lemon-yellow precipitate which did not dissolve in excess of the reagent.

6. Heller's nitric acid test. (a) No precipitate at junction of the two liquids at first. White precipitate plainly visible on standing 24 hours. (b) White precipitate within a few minutes. Control with egg albumen gave a white zone of precipitated albumin at the point of juncture.

7. Sodium chloride-acetic acid. (a) Whitish precipitate in small particles either at once or on boiling. (b) Whitish precipitate as in (a) but more abundant. Control with egg albumen gave a white precipitate.

8. Acetic acid-potassium ferrocyanide. (a) Precipitate in loose mass at the end of 24 hours. (b) Precipitate formed at once. In some cases precipitate so abundant as to be almost coagulum-like, but in those cases separating into fine particles on dilution. Control with egg albumen gave a precipitate.

9. Lead acetate. (a) No test made. (b) Equal volumes of concentrated KOH and sieve tube extract were mixed. Two drops of lead acetate solution were added and the solution was boiled. The solution became dark. The control with egg albumen gave like results.

Tests with Fehling's solution were also made with the following results. (a) *Very* slight reduction. (b) Distinct reduction in one case only. *Very* slight reduction or none at all in other cases.

The results with Millon's reagent are very similar to those with the control of egg albumin. These results might, of course, be due to the presence of non-protein material. If we assume that the results are due to the presence of a protein or proteins, they seem to indicate a tyrosine complex.

The Xanthoproteic test is positive, except that no orange color appeared. The results suggest the presence of a protein or proteins having a complex of one or more of the following: tyrosine, phenylalanine, tryptophane.

The results with the biuret test are fairly similar to those with the control. The results may, of course, be due to the presence of non-protein substances having the requisite amino groups, or they may be due to the presence of proteins.

Picric acid is, of course, an alkaloidal reagent as well as a protein reagent. The results obtained are, however, consistent with the presence of a protein or proteins in the solutions tested.

The results with Heller's nitric acid test seem consistent with the presence of proteins. The sodium chloride-acetic acid test and the acetic acid-potassium ferro-cyanide test, indicate the presence of albumin. The lead acetate test indicates the presence of unoxidized sulphur, and suggests the presence of a protein or proteins containing sulphur.

There have been many determinations of nitrogen in the fronds and the stipe of this plant. The average of a considerable number of analyses by various workers on material including both fronds and stipe indicates 0.14% of nitrogen in *fresh* material (Rigg 1916). Hoagland (1915) found 1.8% of nitrogen in the *dried* material, the amount in non-protein form being 0.46% If we take the difference between these two and multiply by 6.25 we get 8.37% as an estimate of the amount of protein present in *dried* material. His results indicate a much greater protein content in fronds than in stipes. In *dried* fronds he found 1.27% of sulphur, over  $\frac{1}{8}$  of which was organic. In the stipe he found 0.45%, of which nearly  $\frac{3}{4}$  was organic. The exact figures are 0.45% in fronds and 0.31% in stipes. He says that fronds have a uniformly higher content of sulphur than stipes.

Wille (1897) finds evidence that in those kelps which shed their leaves and form new ones, nutritive materials are moved from old leaves to new ones. He believes that the structure of the sieve tubes and their position in the thallus, leaves no doubt that they are organs of translocation. He thinks that the materials translocated by them are probably not proteins because (1) their total protein content is so small and (2) the cell contents of these tubes have such an evident foam structure that they are scarcely suitable for the conduction of viscous proteins. He suggests further investigation as to whether they are amides, carbohydrates or other plastic materials.

Taken altogether the results of the protein tests reported in this paper indicate the presence of water-soluble proteins in the sieve tubes of this kelp. Taken in connection with the work on the occurrence of proteins and of organic sulphur in the fronds and in the stipe, they suggest that such substances are probably translocated from regions of synthesis in the fronds to regions of use in the stipe and the holdfast.

Reducing sugars seem to be absent from these tubes or, at most, present only occasionally and then in very small amounts. Analyses by other workers indicate a general absence of reducing sugars from the fronds and stipes of this species, as well as from some other kelps. Hoagland (1915) boiled ground dried material for 10 hours with a 2% sulphuric acid solution. On analyzing this with Fehling's solu-

tion he got the following amounts of reduced copper calculated as dextrose: fronds 5.6%, stipes 5.7%. He says that "acid hydrolysis yielded copper-reducing substances only with great difficulty," and that the carbohydrates of this and other kelps "are complex colloidal substances, which would ordinarily be classified among the vegetable gums, or pectins."

#### MICROCHEMICAL TESTS

The work on the cell walls was of two kinds.

1. Staining. The walls stained yellow with iodine ( $I_2KI$ ). They also stained with ruthenium red and with methylene blue. In some cases they showed a faint violet color with 50% sulphuric acid followed by iodine ( $I_2KI$ ) though in many cases the results were entirely negative. Controls of cotton fibers and filter paper were run in all cases with this test and always showed positive results. The walls were not stained with eosin after clearing with glycerine. They did not stain with picric acid. The biuret test was negative.

(2). Solubility. The walls were completely disintegrated by treating for 3 days with sodium carbonate. If there was material in them that was not dissolved by this treatment, it was not of sufficient amount to enable the walls to retain their form. When placed on a glass slide with solid ferric chloride and heated over a water bath until the chloride melted, and then further heated in the same manner, the walls were not dissolved, but were so weakened that they were readily broken up by manipulation with dissecting needles. Controls of cotton fibers and filter paper treated in the same way dissolved in a very short time. The walls of sieve tubes were not dissolved by prolonged treatment with cold 3% KOH. On boiling 10 minutes in the solution, the walls were not dissolved but were much swollen. Some of the walls were dissolved, or at least disintegrated by boiling 10 minutes in 5% KOH. The walls of practically all sieve tubes were dissolved or disintegrated by boiling a few minutes in 50% KOH.

These results indicate clearly that these cell walls are composed of more than one substance. Their behavior with iodine, with sulphuric acid and iodine, and with ferric chloride is consistent with the conclusion that they contain some cellulose. The behavior with ruthenium red, with sodium carbonate, and with potassium hydroxide seem to indicate pectin material. The sodium carbonate test might indicate algin (Hoagland 1915), but the distinction between pectin and algin does not seem to be sharply drawn. If their behavior with potassium hydroxide indicates pectin, it is of a very resistant sort (cf. Molisch 1913, p. 316). Karrer (1916) found that the cell walls

of fronds, stipes and holdfasts of this plant are made up of cellulose and algin. Sykes (1908) found that the cell walls of kelps closely related to the bladder kelp (*Macrocystis* and *Laminaria*) are composed of cellulose and pectose.

Wille (1897) has found that the cell walls of *Alaria esculenta* and other *Laminariaceae* are composed of an inner layer of cellulose and an outer layer of "intercellular substance." In *A. esculenta* this was true of sieve tubes as well as of ordinary cells of the frond. It was also true of "Verbindungs-hyphen" except that the cellulose wall was thinner than in other cells. He found calcium in the "intercellular substance." The material left after the removal of the calcium he calls "Taugsäure." The fact that it tended to go into solution readily in weak alkalis suggests the substance or mixture of substances that now goes under the name of alginic acid. He believes that the calcium is very important in holding the cells together.

Staining tests and solubility tests were made on the sieve plates.

(1) Staining. They stain brown with iodine, red with corallin, and very strongly red with ruthenium red. They give a blue color with sulphuric acid followed by iodine. They retain little or no color when treated with eosin and cleared with glycerine.

(2) Solubility. They are not dissolved by prolonged treatment with cold 3% KOH nor by boiling in it for 10 minutes. Those in the older tubes are dissolved by boiling for a few minutes in 5% KOH, and some in the older tubes are dissolved by prolonged boiling in the same solution. Boiling in 50% solution of KOH soon dissolved many, both old and young. Many were dissolved or at least disintegrated by treatment for 2 days with cold dilute sodium carbonate. Cells sometimes come apart at the plate under certain treatment, though the plate is not destroyed (Fig. 8).

These results do not point clearly to any one substance. The following interpretation of results is based mainly on the statements made by Tunmann (1913, p. 557) in regard to tests for callose. Their behavior with ruthenium red is not especially significant, since it stains several substances. Their behavior with iodine, with corallin, and with eosin indicate callose. If their behavior with potassium hydroxide indicates callose, it must be of a very resistant kind since the cold 1% solution should readily dissolve this substance. Their behavior with sodium carbonate suggests that their callose content is small, since that substance is insoluble in cold alkaline carbonates. Their solubility in this reagent suggests pectin or algin. Their behavior with sulphuric acid followed by iodine suggests a cellulose-like substance.

Sykes (1908) found that sieve plates in kelps are composed of "something more resistant than pectose."

The callus masses stain yellow or yellow-brown with iodine, slightly red with eosin after clearing in glycerine, blue with very dilute methylene blue and with aniline blue, and also with Berlin blue, and red with ruthenium red. With picric acid they stain yellow in some material and do not stain at all in other material. Negative results were obtained with the biuret test, the xanthoproteic test, and Millon's reagent.

In many of the tubes that do not show callus masses, the protoplasm near the sieve plates displays the staining properties of the callus masses. There is no sharp line of division between the protoplasm having these staining properties and that farther from the sieve tubes, which does not have them; the one merges gradually into the other.

The behavior of the callus masses with all of the above reagents was the same in material that had been boiled for 30 minutes in distilled water that it was in fresh material. In material that had been boiled for 30 minutes in distilled water, then extracted for 11 hours with cold 72% alcohol, and finally with hot 5% sodium chloride, the behavior with all of the reagents was the same as that with fresh material, except that the staining with ruthenium red was a little less marked, and that a blue color was shown by treatment with 50% sulphuric acid followed by iodine ( $I_2KI$ ). In material that had been boiled 30 minutes in 3% potassium hydroxide, allowed to stand 3 days in the cold solution and then washed with distilled water, iodine ( $I_2KI$ ) gave a distinctly blue color to these callus masses.

These callus masses are not dissolved in cold dilute sodium carbonate, nor in hot ferric chloride. They are not dissolved, though they are sometimes swollen and distorted by treatment for several hours with cold 1% potassium hydroxide. They are not dissolved by boiling for 10 minutes in 3% potassium hydroxide but are dissolved by rather prolonged boiling in a 50% solution of this reagent.

In the main these results are consistent with the view that the substance forming the callus masses is a special carbohydrate chemically distinct from cellulose and pectose, which received the name callose from Mangin in 1892 (Haberlandt 1914, Molisch 1913, Tunmann 1913). This name was applied to the callus masses occurring in the sieve tubes of seed plants and the citations given refer to discussions of it in seed plants. Sykes (op cit.) says (p. 316) that callus is a hydrated form of cellulose and (p. 315) that the extent of hydration



in callus masses of *Laminaria* varies with the season, being less in summer than in winter. In general he found the callus of *Macrocystis* more hydrated than that of *Laminaria*.

The results obtained by the writer with iodine, with corallin, and with sodium carbonate suggest callose. Their behavior with potassium hydroxide suggests an unusually resistant form of callose. Their behavior with eosin is consistent (Tunmann op. cit. p. 410) with protein content and emphasizes their similarity to the content of the sieve tubes in higher plants (Tunmann 1913, p. 557). Oliver (1887) says that the callus of *Macrocystis* and *Nereocystis* is identical in all of its microchemical reactions with the callus of phanerogamic sieve tubes, and may be regarded as chemically the same substance. Their behavior with picric acid is consistent with the presence of protein material. Their behavior with the biuret test, the xanthoproteic test and with Millon's reagent indicates the absence of such protein groups as correspond to these tests or the presence of something that interfered with the tests.

Their behavior with the ferric chloride fails to indicate any cellulose content. Their blue color with sulphuric acid and iodine ( $I_2KI$ ) in material boiled in water and then extracted successively with alcohol and sodium chloride suggests that either something was modified to a cellulose-like substance by the treatment or that something was removed that made the test plain. It is noted below that the protoplasm sometimes gave a cellulose test with these reagents in fresh material.

It seems evident that the callus masses of this kelp, so far as examined and tested by the writer originate mainly from the protoplasm. He has seen no positive evidence, however, to indicate that nothing in them comes from the sieve plates. The fact that they are in contact with the sieve plates accords with either theory of their origin. The fact that the callus mass sometimes surrounds the protoplasm for some distance back from the sieve plate, the protoplasm extending through a tube-like opening in the callus mass nearly or quite to the sieve plate (Fig. 7), also seems consistent with either view, though in the main the appearance is such as to suggest origin from the protoplasm. The writer has seen no evidence to indicate that they originate from the side walls of the sieve tubes.

Oliver (1887) says that these callus masses are formed by an alteration of the cell wall. Sykes (1908, p. 304) says that there seems to be no doubt that the mass of callus in *Macrocystis* is laid down by the protoplasm and is not formed by an alteration of "the

cell wall already present." In *Laminaria saccharina* and *L. digitata* he says that the callus "appears to be produced in the young sieve plates by the action of a ferment on the already formed cell wall, but is afterward accumulated by deposition from the protoplasm, both on the surface of the sieve plate and on the lateral walls of the tube." He says that in some cases in *Macrocystis* the "protoplasm lays down callus throughout the entire length of the tube, the callus appearing first as a thin line on the edge of the protoplasm, and later becoming more extensive, often entirely blocking the tube. He states also that the callus of *Macrocystis* gives all of the reactions characteristic of ordinary callus found in the sieve tubes of phanerogams. He further finds that the sieve tubes of *Nereocystis* appear very similar to those in *Macrocystis* and that in some cases there could be no doubt that the callus was deposited from the protoplasm.

The distribution of these masses with reference to the sieve plates suggests their correlation with translocation of material in one direction through the sieve tubes. Sykes (1908, p. 304) says that callus in the kelps that he examined usually accumulates much faster on the side of the sieve plates farther from the apex.

In the following statement of results the use of the word protoplasm is not intended to distinguish between true protoplasm and any slimy material that may replace it as cells grow older. The protoplasm stains with methylene blue, and gives a brown color with potassium permanganate. It does not stain with ruthenium red.

Microchemical tests were applied as suggested by Tunmann (1913, pp. 410-414). With iodine ( $I_2KI$ ) the protoplasm stains brown or yellow. When material is boiled 30 minutes in distilled water and then treated with  $I_2KI$  solution the protoplasm shows a pale yellow color. The biuret test gives a blue or violet color. Eosin gives the protoplasm a red color, which persists when cleared in glycerine. Picric acid gives a yellow color. The test with Millon's reagent is negative. In cells in which there are no callus masses, the indications of proteins are often more positive near the sieve plates than elsewhere, and often more on one side of the plate than on the other. With some of the reagents, special granules or sometimes masses (Fig. 18) showed stronger reaction than did the rest of the protoplasm. These masses were usually small, but were sometimes so large as to fill the tube for a short distance (Fig. 15). These were especially evident with picric acid,  $I_2KI$ , and eosin. Haberlandt (1914) states that in older sieve tubes of higher plants "a number of highly refractive homogeneous slimy globules of protein material appear within the peri-

pheral protoplasm." With 50% sulphuric acid followed by I<sub>2</sub>KI solution the protoplasm gives a pale blue color. No evidence of reduction is seen when Fehling's solution is applied.

The indications seem to be that the proteins, whose presence is indicated by macrochemical tests on water extracts, are present in the protoplasm. The fact that they show a tendency to accumulate near the sieve plates, often more on one side than on the other, seems to confirm the view that they are being translocated by these tubes, accumulating there as translocation becomes less rapid.

No evidence of reducing sugars in the protoplasm was found. The fact that the protoplasm responds to a cellulose test is to be considered in connection with the fact that the callus masses respond to this test with certain treatments.

#### SUMMARY AND CONCLUSIONS

1. The gross anatomy of this plant suggests that the sieve tubes conduct materials from points of synthesis, mainly in the fronds, to points of use or of temporary storage in the stipe. This tends to confirm the view taken by other workers.

2. The macroscopic anatomy of the sieve tubes confirms this view.

3. The macrochemical tests on water extracts from these tubes indicate the presence of proteins.

4. Microchemical tests confirm the presence of proteins and indicate that they are in the protoplasm, and are probably being conducted through the sieve tubes.

5. The callus masses seem to originate from the protoplasm and to be correlated with the increasing age of the sieve tubes and their tendency to become functionless.

6. Branches connect old tubes with younger ones and it seems probable that material is transferred from the former to the latter as the work of conduction shifts in the same direction.

7. It does not seem probable that carbohydrates are conducted by these tubes in any important amounts.

8. This work was all done between June 15 and July 30, and all conclusions reached must be considered as applying to that season only.

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## PLATE 37

FIG. 2. Vertical section through a portion of a pneumatocyst and small portion of a frond. *a*, Pneumatocyst wall; *b*, base of frond; *c*, medulla of frond extending to mass of pith web, *d*.  $\times 0.5$ .

FIG. 3. A sieve plate (*a*) with portions of two sieve cells (*b, b'*) with protoplasm (*c, c'*) in each. Fresh material stained with dilute eosin and cleared with glycerine. The shading indicates the extent of staining.  $\times 390$ .

FIG. 4. A sieve plate (*a*) with portions of two sieve cells (*b, b'*), two callus masses (*c, c'*) and protoplasm (*d, d'*). Fresh material mounted in aniline blue. not treated with any reagents.  $\times 350$ .

FIG. 5. A sieve plate (*a*) with portions of two sieve cells, two callus masses and protoplasm in the center. Fresh material mounted in aniline blue. Callus masses stained blue.  $\times 350$ .

FIG. 6. A sieve plate (*a*) with portions of two sieve cells (*b, b'*) and two callus masses (*c, c'*) showing apparent layers. Fresh material boiled 30 minutes in distilled water, extracted 11 hours with cold 72% alcohol, then mounted in Berlin blue. Callus masses stained blue.  $\times 350$ .

FIG. 7. Sieve plate (*a*) with portions of two sieve cells (*b, b'*) and two callus masses (*c, c'*) with protoplasm (*d*) present in one cell, and extending through the callus mass to the sieve plate, but not present in the other. Callus masses stained with methylene blue.  $\times 350$ .

FIG. 8. Sieve cells (*a, a'*; *b, b'*) separating at plates. Material boiled in distilled water, extracted 20 hours with cold 72% alcohol, then 4 hours in cold 5% NaCl and finally boiled a few minutes in the latter solution. Mounted in 5% KOH.  $\times 85$ .

FIG. 9. A sieve plate (*a*) with portions of two sieve tubes (*b, b'*) and callus masses (*c, c'*). Fresh material mounted in distilled water.  $\times 350$ .

FIG. 10. Sieve plate (*a*) with portions of two sieve tubes (*b, b'*), a callus mass (*c*) in one, and protoplasm (*d, d'*) in both. Fresh material boiled in dilute KOH, washed in distilled water and mounted in I<sub>2</sub>KI. The callus mass was stained blue. The protoplasm near the callus mass was slightly blue, but farther away it was unstained.  $\times 350$ .

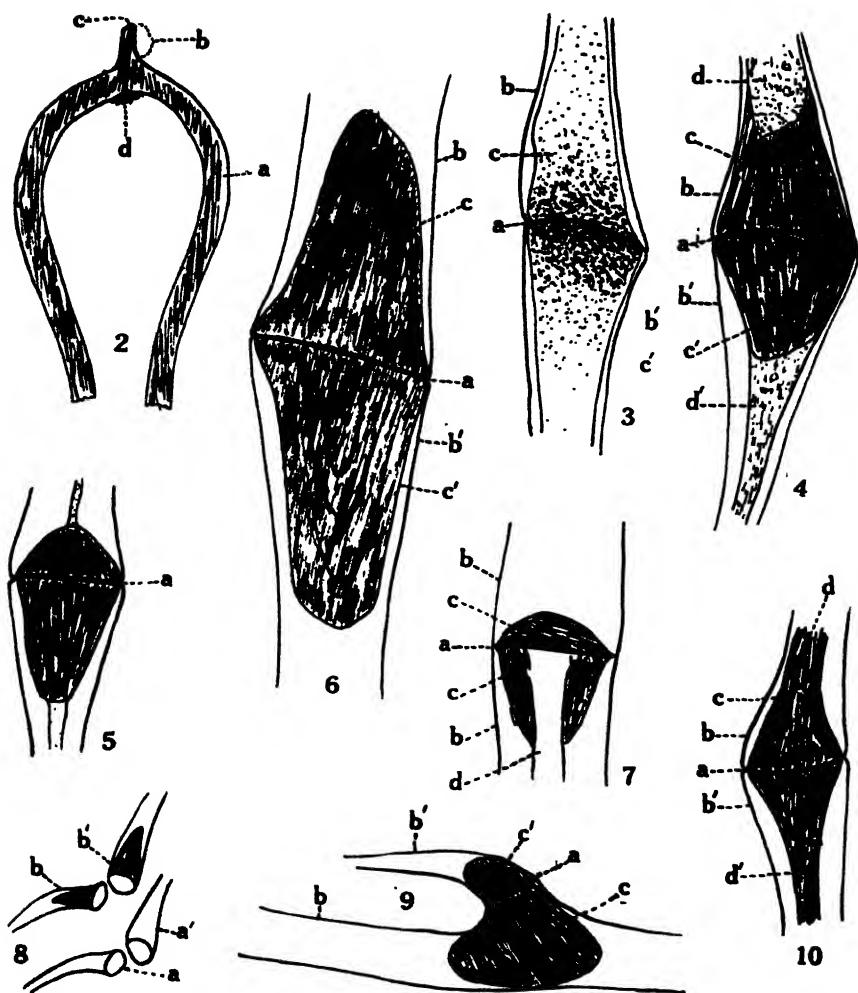


PLATE 37

## PLATE 38

FIG. 11. A sieve tube (*a*) with a filament (*b*) twining around it.  $\times 390$ .

FIG. 12. A callus mass (*a'*) flowing out of the broken end of a sieve cell. Fresh material boiled 15 minutes in distilled water, extracted 20 hours with cold 72% alcohol and 1 hour with hot 5% NaCl. Mounted in I-KI.  $\times 350$ .

FIG. 13. A callus mass (*a*) slipping from a sieve cell (*b*) that had broken away from its plate. Fresh material boiled 30 minutes in 3% KOH and allowed to stand in the same solution 3 days. Mounted in distilled water.  $\times 350$ .

FIG. 14. Two sieve tubes (*a, a'*) with a branch connecting them.  $\times 85$ .

FIG. 12. A callus mass (*a*) flowing out of the broken end of a sieve cell. of apparently dead protoplasm (*c, c'*). Fresh material treated with distilled water, then absolute alcohol and mounted in I-KI. Mass distinctly yellow brown, protoplasm faintly yellow brown.  $\times 390$ .

FIG. 16. Small yellow masses of material (*a, a'*) in a narrow tube from pith web. Same treatment as in Fig. 15.  $\times 390$ .

FIG. 17. Mass of material (*a*) flowing from the broken end of a sieve tube in material teased out with needles. Fresh material mounted in picric acid. The mass was bright yellow. Apparently the tube except the central channel from which this mass flowed was filled with callus.  $\times 390$ .

FIG. 18. Two sieve plates (*a, a'*) with portions of three sieve cells (*b, b', b''*) and protoplasm (*c, c'*) showing masses (*d, d', d''*) of yellow material. Fresh material mounted in picric acid.  $\times 350$ .

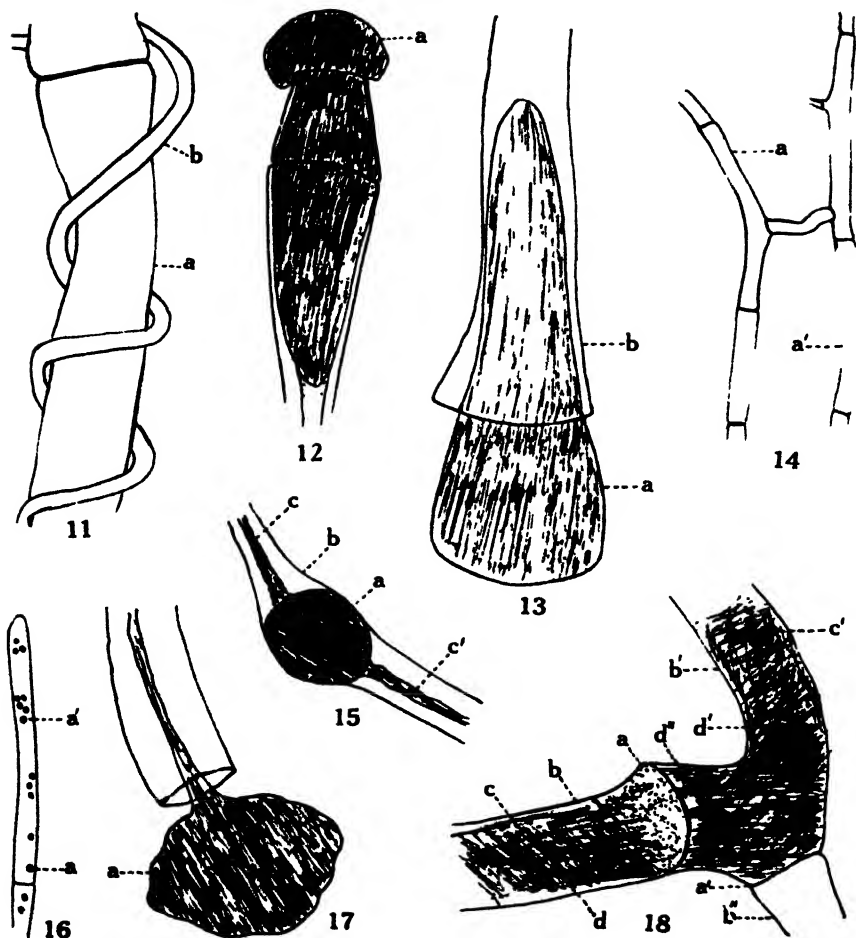


PLATE 38





## Some Enzymatic Actions of *Nereocystis Luetkeana*

LEONA SUNDQUIST

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The purpose of this work was to determine whether the presence of carbohydrases and pentosanases in *Nereocystis luetkeana* could be demonstrated. The work was commenced at the Puget Sound Biological Station in the summer of 1922. In general, the procedure followed that of former workers.

Attempts have been made by various workers to determine the extent of enzyme action in marine algae. The enzymes which they found were relatively few in number, especially so in the Phaeophyceae. The presence of diastase in a number of red algae was determined by Bartholemew (1914). Davis (1915) quantitatively determined the action of diastase in some members of this same group as well as in a few green algae. In the brown algae, negative results predominate. Davis (1915) worked on *Laminaria agardhii*, *Ascophyllum nodosum* and *Mesogloea divaricata*, and found slowly acting carbohydrases in *Laminaria* only. In his paper he cites Torup in 1909 as having extracted an enzyme from fresh *Laminaria* that hydrolysed laminarin to dextrose. Repeated negative results were obtained by Duggar and Davis (1914) in their work on *Fucus vesiculosus*, in determining the presence of a diastase and a pentosanase. The preponderance of negative results in the brown algae stimulated interest in the possibility of enzymatic actions in *Nereocystis luetkeana*, which is a very large, vigorous and rapidly growing plant.

### MATERIAL AND APPARATUS

In order to insure clean, whole material in the most natural condition it was gathered from kelp beds of medium depth where the tide was swift. The growing region of the frond (60-90 cm. of the blade near the pneumatocyst) and well formed but not fully developed fruiting patches were selected.

As soon as the material was cut it was immediately cleansed of any adhering plant or animal life. The tubs of material were then placed under running salt water, which removed the greater part of the slime and foreign matter. After two hours each blade was separately washed under running fresh water. In this process minute animals overlooked in the former washings would release themselves. The fruiting patches were treated in the same way.

After drying the surfaces of the fronds and fruiting patches a portion was then ground and the enzyme extract prepared. The remainder was dried in a warm attic until it became crisp. Direct sunlight was avoided. Care was taken here to insure drying as rapidly as possible, at a moderate temperature, so that the material would not spoil. It was then packed in paper bags and cartons, and stored in a darkened room.

The extraction and precipitation of the enzyme material was done in 500 cc., 1 liter, and 2 liter beakers. The starch solutions were boiled in an Erlenmeyer flask attached to a reflux condenser. The pentosan and the enzyme precipitates were dissolved in 100 cc. beakers. The digestion process was carried on in large test tubes closed with cotton stoppers. Testing for reducing sugars was done in smaller test tubes.

Great care was taken to keep the apparatus clean. Immediately after using, each piece was thoroughly washed in hot soap water, then rinsed in hot water, filled with potassium dichromate cleaning solution and allowed to stand. Later they were thoroughly rinsed in tap water and finally in distilled water.

#### EXTRACTIONS AND TESTS

In the extraction of enzyme from fresh material the fronds were ground to a very fine pulp by passing them through a meat grinder three times. 600 cc. of pulp and 400 cc. of distilled water were thoroughly mixed and allowed to stand over night. Toluene was added as an antiseptic. The mixture was repeatedly filtered through many thicknesses of cheese cloth. From 400 cc. of juice, the enzyme was precipitated with 95 per cent ethyl alcohol. To get the best results two to three volumes were needed. The precipitate was immediately filtered. No further purification seemed necessary. This precipitate was dissolved in 100 to 200 cc. of distilled water, the amount varying with the sliminess of the solution. This enzyme solution was ready for immediate testing. The fresh fruiting patches were treated in the same manner.

In the extraction of enzyme from dry material this was ground to a fine powder with a meat grinder. To 10 g. of ground fronds, 300 cc. of distilled water was added, together with toluene. This was allowed to stand over night. From 100 to 180 cc. of juice the enzyme was precipitated with 2 to 4 volumes of 95 per cent ethyl alcohol. The enzyme precipitate was then dissolved in 85 cc. of distilled water. This enzyme solution was ready for immediate testing.

With a few exceptions, the different starch solutions were prepared by the same method: i. e., to 1 g. of pure starch, 100 cc. of distilled water was added and the solution boiled under a reflux condenser for 1½ to 2 hours. This insured a thorough breaking down of the starch grains and a permanent suspensoid. The exceptions to this method of preparation were unsuccessful as substrates.

The pentosans used were cherry gum and gum arabic. Care was taken to select as pure material as possible. To 1 g. of each, 100 cc. of distilled water was added and the mixture allowed to stand until dissolved. The substrates were prepared just before using.

In general, to a given amount of starch or pentosan solution twice the amount of enzyme solution was added. Toluene was always used as a preservative. The tests made from the fresh material were allowed to remain 4 days at the temperature of the laboratory. This room was cold and damp, being over the water. The tests made from the dried material were kept in a thermostat for 16 hours, at a temperature of 34° C. The action of the enzyme upon the starches and pentosans was tested with either Fehling's or Benedict's solutions.

Fifty series of tests were made upon the various starch solutions, in the manner indicated in tables 1 and 2, with extracts from fronds and fruiting patches. The results of 48 were positive. Duplicate controls were used in all experiments. In table 1 the experiments were conducted at laboratory temperature, and at least 4 days were required for appreciable action. In 15 tests in this table the enzyme solutions were boiled for two minutes. In table 2 the experiments were continued for 16 hours at 34° C.

Table 3 is typical of 20 experiments using cherry gum and gum arabic as substrates. Potato starch controls were used in addition to those of the previous experiments. The experiments were continued for 16 hours at 34° C. In one experiment fruiting patches were tried, the results corresponding with the table.

TABLE 1. *Enzyme solutions from fresh material of either fronds or fruiting patches.*

20 cc enzyme solution	plus 10 cc potato starch	reduction
20 cc enzyme solution	plus 10 cc potato starch	reduction
20 cc enzyme solution boiled	plus 10 cc potato starch	reduction (slight)
20 cc enzyme solution boiled	plus 10 cc potato starch	reduction (slight)
20 cc distilled water	plus 10 cc potato starch	no reduction
20 cc distilled water	plus 10 cc potato starch	no reduction
20 cc enzyme solution	plus 10 cc distilled water	no reduction
20 cc enzyme solution	plus 10 cc distilled water	no reduction

TABLE 2. *Enzyme solutions from dried material of either fronds or fruiting patches.*

6 cc enzyme solution	plus 3 cc distilled water	no reduction
6 cc enzyme solution	plus 3 cc distilled water	no reduction
6 cc enzyme solution	plus 3 cc potato starch	reduction
6 cc enzyme solution	plus 3 cc potato starch	reduction
6 cc distilled water	plus 3 cc potato starch	no reduction
6 cc distilled water	plus 3 cc potato starch	no reduction
6 cc enzyme solution	plus 3 cc arrowroot starch	reduction
6 cc enzyme solution	plus 3 cc arrowroot starch	reduction
6 cc distilled water	plus 3 cc arrowroot starch	no reduction
6 cc distilled water	plus 3 cc arrowroot starch	no reduction
6 cc enzyme solution	plus 3 cc corn starch	reduction
6 cc enzyme solution	plus 3 cc corn starch	reduction
6 cc distilled water	plus 3 cc corn starch	no reduction
6 cc distilled water	plus 3 cc corn starch	no reduction
6 cc enzyme solution	plus 3 cc tapioca starch	reduction
6 cc enzyme solution	plus 3 cc tapioca starch	reduction
6 cc distilled water	plus 3 cc tapioca starch	no reduction
6 cc distilled water	plus 3 cc tapioca starch	no reduction
6 cc enzyme solution	plus 3 cc sago starch	reduction
6 cc enzyme solution	plus 3 cc sago starch	reduction
6 cc distilled water	plus 3 cc sago starch	no reduction
6 cc distilled water	plus 3 cc sago starch	no reduction
6 cc enzyme solution	plus 3 cc soluble starch	trace
6 cc enzyme solution	plus 3 cc soluble starch	trace
6 cc distilled water	plus 3 cc soluble starch	no reduction
6 cc distilled water	plus 3 cc soluble starch	no reduction

TABLE 3. *Enzyme solutions from dried fronds.*

10 cc enzyme solution	plus 5 cc distilled water	slight reduction
10 cc enzyme solution	plus 5 cc distilled water	slight reduction
10 cc distilled water	plus 5 cc potato starch	no reduction
10 cc distilled water	plus 5 cc potato starch	no reduction
10 cc distilled water	plus 5 cc cherry gum	slight reduction
10 cc distilled water	plus 5 cc cherry gum	slight reduction
10 cc distilled water	plus 5 cc gum arabic	very slight reduction
10 cc distilled water	plus 5 cc gum arabic	very slight reduction
10 cc enzyme solution	plus 5 cc potato starch	much reduction
10 cc enzyme solution	plus 5 cc potato starch	much reduction
10 cc enzyme solution	plus 5 cc cherry gum	reduction
10 cc enzyme solution	plus 5 cc cherry gum	reduction
10 cc enzyme solution	plus 5 cc gum arabic	reduction
10 cc enzyme solution	plus 5 cc gum arabic	reduction

With Dr. H. Kylin's assistance a substance was extracted from kelp which was soluble in water and when hydrolyzed with HCl yielded reducing sugars. As no polariscope was available, it was impossible to identify this substance definitely as a laminarin, similar to that which has been extracted from *Laminaria*. During the winter, further attempts were made to extract this substance. The writer was unable to extract an amount sufficient to test whether it would be hydrolyzed by the kelp extract.

## DISCUSSION

All those tests in which the enzyme extract was prepared from the fruiting patches indicated hydrolysis of starch, showing a reduction of Fehling's solution. Two of the frond extracts failed to hydrolyze starch. The first of these occurred with potato starch as the substrate. The same precautions were taken with this experiment as with the 48 which were successful and the writer is unable to attribute the failure to any particular conditions. The cause of the second failure was due to soluble starch, which was uncooked. In every case when it had been boiled for 2 hours under a reflux, hydrolysis was apparent; but the reduction of Fehling's solution was slight as compared with that of the other starches used as substrates. In those experiments in which the enzyme solution was boiled for 2 minutes, heat proved to have an inhibitory effect upon the action of the enzyme, for if hydrolysis of starch occurred at all, there was merely a trace of reduction. It is very evident from the results of these experiments, on six different starches as substrates, that there is in kelp a carbohydrase which has the power of hydrolyzing the starches of higher plants to reducing sugars.

The potato starch controls (table 3) served to verify the presence of a carbohydrase as well as to compare the amount of pentosan hydrolysis with that of potato starch. In some cases the enzyme controls showed a reduction of Fehling's solution. This may be due to the length of time the material had been stored, for these particular tests were made in March, 1923, while those using the starches alone as substrates were completed before the first of September in 1922. The pentosan controls showed a reduction of Fehling's solution as well as the enzyme controls. The enzyme plus cherry gum and the enzyme plus gum arabic also showed a reduction of Fehling's solution, but it was difficult to determine if this amount was larger than the combined amounts of the two corresponding controls. In some experiments it seemed to be a great deal more, while in others it was about the same. In those cases in which digestion seemed to take place, gum arabic appeared to be more readily attacked than cherry gum. Although the enzyme solution in some cases showed a reduction of Fehling's, the amount of reduction in the case of the potato substrate plus the enzyme was a great deal more. The amount of this digestive activity far exceeded that which seemed apparent, at times, in the pentosans plus the enzyme. Thus the presence of a carbohydrase was verified but that of a pentosanase was not established. In order to determine if there is an actual difference between the amount of pento-

san hydrolysis and that of the controls, quantitative methods must be used.

#### SUMMARY

1. The presence in *Nereocystis luetkeana* of a substance which hydrolyzes the starches of higher plants to reducing sugars was definitely determined.

2. The digestive activity of this substance is inhibited by heat.

3. A water soluble substance was extracted which yields reducing sugars when hydrolyzed with HCl.

4. The presence of a substance which hydrolyzes pentosans to pentose sugars was not definitely determined. To establish its presence quantitative methods are necessary.

The writer is indebted to Dr. G. B. Rigg, at whose suggestion the work was started, for advice and criticisms, and to Dr. H. Kylin for assistance in the carbohydrate extraction.

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## ANNOUNCEMENT

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**The Alkaline Reserve of the Blood Plasma of the Viviparous  
Perch (*Cymatogaster aggregatus* Gib.) in Relation to the  
Carbon Dioxide Tension, the Oxygen Tension  
and the Alkalinity of the Sea Water \***

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and

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INTRODUCTION

The balance between acids and alkalies or the  $C_H$  of the blood is regarded by all physiologists as one of the most important of the equilibria of the body of the higher and presumably the lower animals as well. Haldane (1922) in his book, "Respiration," says, "A rise of 0.2 per cent or 1.5 mm. in the  $CO_2$  pressure of the alveolar air and arterial blood causes an increase of about 100 per cent in the resting alveolar ventilation, and from Figure 54 it will be seen that this corresponds to a difference of .012 in  $p_H$ . This difference, large as its physiological effect is, cannot be detected with certainty by the electrometric method, or by indicators, and is quite undetectable by the shifting of the dissociation curve of oxyhaemoglobin. Nevertheless a twentieth of this difference would produce an easily measurable effect on the breathing or alveolar  $CO_2$  pressure. The astounding delicacy of the regulation of blood reaction is thus evident. No existing physical or chemical method of discriminating differences in reaction approaches in delicacy the physiological reaction." This acid-base equilibrium in higher organisms is maintained for the greater part through the delicate response of the respiratory mechanism in bringing about slight or great changes in alveolar ventilation (Haggard and Y. Henderson 1919). Other compensations occur, such as the passage of alkali from the blood to the tissues or vice versa (Y. Henderson and Haggard 1918), excretion by the kidneys (L. J. Henderson 1908) and the neutralization of acids in the liver. But as Haldane states (1922), "The part played by the lungs in this regulation is, quite clearly, to

\*Contribution from the Puget Sound Biological Station of the University of Washington, and from the University of Tennessee.

deal rapidly with variations in reaction due to varying production of  $\text{CO}_2$ . The action of the liver and kidneys seems slower but more delicate.

From work that has been done (Powers 1921, 1922, 1922a and 1923) the question presents itself, has a fish a mechanism by which a rapid compensation in the acid-base equilibrium is brought about? And, what relation has this to the habits, habitats and migratory movements of fishes, especially marine fishes? There is abundant evidence that there are daily and in some cases hourly variations in the  $\text{CO}_2$  tension of shore sea water (L. J. Henderson and Cohn 1916, McClendon 1917, Powers 1920 and Legendre 1922), inshore and offshore sea water and seasonal variations in each (Atkins 1922) and in different ocean currents (Meyer 1919). In addition to this, there is obviously a variation in the  $\text{CO}_2$  production in the body of the fish due to muscular activity. If the acid-base is to be maintained in an equilibrium, i. e., if the  $C_H$  of the blood is to be maintained within at all narrow limits, the fish must remain in sea water of a given  $\text{CO}_2$  tension, it must be able to maintain a given  $\text{CO}_2$  tension in the blood, there must be a rapid compensation by variation in the alkaline reserve of the blood, a modification in the rate of bathing the gills with sea water or some special method of  $\text{CO}_2$  elimination (Collip 1920). There is no reason for believing that there is or are radically different mechanism or mechanisms for maintaining a relatively uniform  $C_H$  of the blood or that a fish is able to withstand at least a very much wider variation in the  $C_H$  of the blood than in higher animals. On the other hand it has been shown by more exact methods of experimentation that the variation in the  $C_H$  of the blood of higher animals compatible with life is much narrower than was at one time supposed. The only differences that one would logically expect in these mechanisms of fishes and higher animals or even different species of animals are the differences in delicacy and the rapidity with which they will respond.

Mechanically the gills of fishes seem less fit than the lungs of higher animals for a rapid compensation for a variation in the  $\text{CO}_2$  production of the body and still less fit to compensate for the rather wide variation in the  $\text{CO}_2$  tensions of inshore waters. Thus, a fish must so regulate its movements as to keep in water with a compatible  $\text{CO}_2$  tension or it must be able to compensate by a rapid change in the alkaline reserve or the  $\text{CO}_2$  capacity of the blood.

Experiments were undertaken on the viviparous perch (*Cymatogaster aggregatus* Gib.) to determine the effect of the  $\text{CO}_2$  tension

and oxygen content of the sea water on the alkaline reserve of the blood plasma. The viviparous perch is especially adapted for this purpose since it enters embayments at high tide where it gives birth to young and then passes to deeper water with the outgoing tide and in so doing this fish must meet with wide and rapid variations in the  $\text{CO}_2$  tensions as well as oxygen contents of the sea water.

### METHODS

In all experiments four female fish were tested.\* Each fish was placed in a gallon fruit jar practically filled with sea water. To one of the jars had been added a small amount of acidulated sea water prepared by adding hydrochloric acid to sea water, to two had been

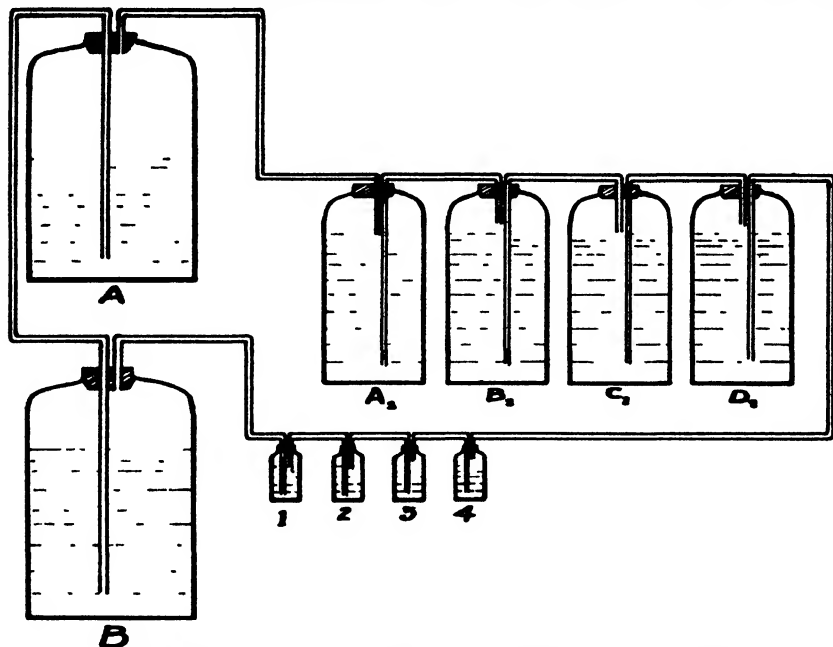


Fig. 1. The siphon A-left-B draws air through the system B-right-A. A and B are interchanged when A is empty; thus the same air is used again. A and B are 18-liter containers; A'-D' are 3.6-liter fruit jars; 1-4 are 250 cc bottles.

added different amounts of alkaline sea water prepared by adding sodium hydroxide to sea water and decanting, and to the fourth jar nothing was added. The four jars were connected in series and

\*The fish for the experiments were caught by stretching a net across the narrow outlet of the upper part of the bay at Deer Harbor, Orcas Island, just as the tide started out. Several hundred females were taken and apparently no males.



aerated by siphoning water from one five gallon bottle into a second five gallon bottle as shown in figure 1. When bottle number 2 was filled with water the places of the two bottles, A and B, were exchanged and the same gas was again forced through the experimental jars. Three 250 cc glass stoppered bottles were placed in the series for oxygen determinations. Since the duration of aeration plus the duration of the experiment in some cases was not sufficiently long to bring the oxygen content and  $\text{CO}_2$  tension of the sea water in all experimental jars into complete equilibrium with that of the gas, this would give only a close approximation of the oxygen content of the sea water of the experiment. The purpose of the experiment was to test a relatively large number of fish with high oxygen and relatively low oxygen at different  $\text{CO}_2$  tensions with varying alkaline reserves of the sea water. There was no attempt to bring the  $\text{CO}_2$  tensions of the waters of the four jars into equilibrium. An attempt was made rather to determine how quickly the blood plasma would respond to a given  $\text{CO}_2$  tension and oxygen content of the sea water. In some of the experiments a fish was taken to test almost as soon as things were made ready after the beginning of an experiment, 20 to 30 minutes. Others were tested as rapidly as time would permit. The relative  $\text{CO}_2$  tensions of the experiments were determined by taking the pH and alkaline reserve of the sea water (L.J. Henderson and Cohn 1916, and McClendon 1917).

The pH of the sea water was determined colorimetrically (Clark 1922), not corrected for salt error, at intervals of 0.02 and estimated as closely as possible. With practice and care in taking samples readings can be made relatively close as was shown by the two of us reading and comparing notes. The oxygen content of the water in the 250 cc bottles was determined by the Winkler method. 100 cc samples were titrated. More nearly exact checks could be obtained by this method than when an attempt was made to calibrate the 250 cc bottles. Bottles of as nearly equal size as possible were used. The alkaline reserve of the sea water was measured in cc of 0.01 normal hydrochloric acid required to change 100 cc of sea water to a pH of 4.2 when methyl orange was used as an indicator and not corrected for salt error. A 15 cc burette graduated to 0.01 of a cc was used. This method was very accurate when exact equivalent amounts of methyl orange were used per 100 cc of sea water and when samples in test tubes of non-soluble glass of the same size and of the same kind of glass as that of the standard were compared with a 4.2 pH buffer methyl orange standard tube by holding the two over white paper

with blue lines. With care checks could be made within 0.01 cc of 0.01 normal hydrochloric acid per 100 cc of sea water.

Blood samples were taken from the caudal artery by severing the tail of the fish and the relative alkaline reserve of the blood plasma was determined by the method described by Marriott (1916) by reading the pH of the blood plasma after its  $\text{CO}_2$  tension had been brought into equilibrium with that of the atmosphere. The greater the alkaline reserve of the blood plasma the higher the pH reading and vice versa.

#### EXPERIMENTAL DATA

Table 1 gives complete data of all experiments. The  $\text{CO}_2$  tensions are only indirectly shown in the table. The data of the four tests of each experiment are arranged in order of the alkaline reserve of the sea water. The data of the experiments are arranged in order of a high  $\text{CO}_2$  tension to a low  $\text{CO}_2$  tension. The four jars of sea water of a given experiment would have comparable  $\text{CO}_2$  tensions. However, the  $\text{CO}_2$  in the four jars was not brought into complete equilibrium with the aerating gas or even to a uniform tension. Our problem was to determine whether or not there were any relations between the alkaline reserve, the  $\text{CO}_2$  tension and oxygen content of the medium and the alkaline reserve of the blood plasma of the fish at all times even though the variation of any one or all of them be comparatively sudden. When column 8 (table 1) is inspected it is seen that with the exception of experiment 9 the average alkaline reserve of each experiment decreases with the decrease in the  $\text{CO}_2$  tension of the sea water. Experiment 9 will be discussed later. A decrease in the alkaline reserve of the blood plasma of the viviparous perch seems to be independent of the hydrogen ion concentration of the sea water as such. Table 2 in which data are arranged in order of the hydrogen ion concentration of the sea water shows this point more forcefully. The 2nd, 3rd, 4th and 5th are data of experiment 9 and are not comparable with the remaining data as suggested above. There is no uniformity in the blood plasma alkaline reserve in relation to the pH of the medium. However, there is on an average a higher alkaline reserve found in the blood plasma when the sea water has a high pH. But as has been stated the lowering of the alkaline reserve of the blood plasma with an increase of the pH of the medium is not sufficiently uniform to warrant the conclusion that this change in the alkaline reserve of the blood plasma is due to the pH of the medium as such. The  $\text{CO}_2$  tension and the pH of the sea water when the tem-

TABLE 1. Showing the effect of the CO<sub>2</sub> tension of the sea water on the alkaline reserve of the blood plasma of the viviparous perch (*Cymatogaster aggregatus* Gib.)

Date of Expt.	No. of Expt.	Time of Expt. in min.	Wt. of Fish in g.	Acid or base added †	Alkaline reserve of water	pH of water	pH of blood plasma	O <sub>2</sub> in cc. per L.	T C°	Remarks
7-21	9	30	18.9	10.0a	8.86	5.60	6.80	2.00	15.40	Gills congested
7-21	9	75	18.9	.....	11.00	5.77	7.15	2.00	15.40	Gills congested
7-21	9	60	23.6	20.0b	11.55	5.80	7.10	2.00	15.40	Gills congested
7-21	9	45	19.2	30.0b	11.79	5.83	7.35†	2.00	15.40	Gills congested
8- 3	11	25	65.8	10.0a	8.73	6.35	7.48	5.30	15.50	Gills congested
8- 3	11	80	18.6	.....	10.86	6.38	7.41	5.30	15.50	Gills congested
8- 3	11	135	21.2	20.0b	11.52	6.20	7.60	5.30	15.50	Gills congested
8- 3	11	120	42.1	30.0b	11.79	6.27	7.45	5.30	15.50	Gills congested
8- 2	10	20	126.1	10.0a	8.93	6.44	7.55	3.81	15.20	Gills congested
8- 2	10	65	29.3	.....	11.16	6.28	7.45	3.81	15.20	Gills congested
8- 2	10	45	36.5	20.0b	11.73	6.25	7.47	3.81	15.20	Gills congested
8- 2	10	30	49.2	30.0b	12.00	6.45	7.53	3.81	15.20	Gills congested
7- 9	2	60	56.9	5.0a	9.98	7.35	7.25	5.50	17.25	
7- 9	2	225	39.7	.....	10.99	7.34	7.40	5.50	17.25	
7- 9	2	280	41.6	10.0b	11.34	7.44	7.44	5.50	17.25	
7- 9	2	119	28.2	15.0b	12.07	7.49	7.47	5.50	17.25	
7-12	4	30	21.4	40.0a	1.93	5.30	7.18*	5.64	15.75	Inactive in 10 min.
7-12	4	190	28.2	.....	10.95	7.45	7.20	5.64	15.75	
7-12	4	125	18.9	40.0b	12.13	7.82	7.36	5.64	15.75	
7-12	4	170	36.3	60.0b	12.63	7.89	7.29	5.64	15.75	
7-17	5	112	44.7	10.0a	9.08	7.25	7.20	5.65	16.10	Few red corpuscles
7-17	5	185	31.6	.....	10.55	7.46	7.22	5.65	16.10	
7-17	5	160	42.1	20.0b	11.20	7.65	7.41†	5.65	16.10	
7-17	5	127	26.3	30.0b	11.40	7.90	7.20	5.65	16.10	
7-24	8	60	28.5	10.0a	8.13	7.16	7.16	0.67	14.35	
7-24	8	130	30.1	.....	10.64	7.56	7.20	0.67	14.35	
7-24	8	111	26.1	20.0b	11.12	7.84	7.18	0.67	14.35	
7-24	8	115	18.9	30.0b	11.95	7.85	7.20	0.67	14.35	
8- 4	12	120	21.2	10.0a	8.54	7.51	7.12	5.90	15.60	
8- 4	12	165	25.2	.....	10.90	7.70	7.21	5.90	15.60	
8- 4	12	221	25.1	(?)	11.02	7.70	7.22	5.90	15.60	
8- 4	12	130	23.1	30.0b	11.79	7.81	7.02†	5.90	15.60	
7-11	3	..	29.8	L.B.**	10.65	7.88	7.35	5.67	15.32	
7-11	3	..	38.2	L.B.	10.65	7.88	7.35	5.67	15.32	
7-11	3	..	40.0	L.B.	10.65	7.88	7.35	5.67	15.32	
7-11	3	..	36.9	L.B.	10.65	7.88	7.07†	5.67	15.32	
7-18	6	..	20.8	L.B.	10.87	7.90	7.45	5.70	15.00	
7-18	6	..	28.6	L.B.	10.87	7.90	7.45	5.70	15.00	
7-18	6	..	33.7	L.B.	10.87	7.90	7.45	5.70	15.00	
7-18	6	..	42.5	L.B.	10.87	7.90	7.45	5.70	15.00	

\*The fish was dead when the blood was taken.

†Obviously errors. Perhaps the high pH of 7.85 and 7.41 are due to contamination with sea water. This is borne out by 7.41 showing few red corpuscles in the blood before it was centrifuged and dialyzed.

‡Obviously an error. This reading has a question mark (?) after it in the notes.

§The letters a and b mean respectively that acid or basic (alkaline) sea water was added.

\*\*L. B. stands for live box.

perature and alkaline reserve are constant vary inversely. In order to analyze the data accurately the alkaline reserve of the sea water must be taken into consideration.

TABLE 2. Showing the alkaline reserve of the blood plasma of the viviparous perch in comparison with the pH of the sea water as such.\*

pH of water	pH of blood plasma	pH of water	pH of blood plasma	pH of water	pH of blood plasma	pH of water	pH of blood plasma
5.30	7.18	6.38	7.41	7.49	7.47	7.88	7.35
5.60	6.80	6.44	7.55	7.51	7.12	7.88	7.35
5.77	7.15	6.45	7.53	7.56	7.20	7.88	7.35
5.80	7.10	7.16	7.16	7.65	7.41	7.88	7.07
5.83	7.35	7.25	7.20	7.70	7.22	7.89	7.28
6.20	7.60	7.34	7.40	7.70	7.21	7.90	7.45
6.25	7.47	7.35	7.25	7.81	7.02	7.90	7.45
6.27	7.45	7.44	7.44	7.82	7.36	7.90	7.45
6.28	7.45	7.45	7.20	7.84	7.18	7.90	7.45
6.35	7.48	7.46	7.22	7.85	7.20	7.90	7.20

The alkaline reserve and oxygen content of the sea water were purposely varied so as to better test the effect of the  $\text{CO}_2$  tension and the pH of the medium as such and their effect in different oxygen contents or tensions. It had already been determined (Powers 1922a) that the alkaline reserve of the blood plasma of the rock-fish (*Sabastodes deani* Starks) could be varied, but the exact factor or factors bringing about this variation were not determined. There was no attempt to measure the  $\text{CO}_2$  tension of the sea water direct since L. J. Henderson and Cohn (1916), and McClendon (1917) have shown that the  $\text{CO}_2$  tension of the sea water with a uniform alkaline reserve and temperature varies inversely as the pH and it was hoped that by certain formulae the  $\text{CO}_2$  tension (free  $\text{CO}_2$  content) could be calculated from data taken. These formulae which have been developed for other purposes could not be utilized for the reason that the ratio of bases in solution as well as that of the anion are varied. However, the  $\text{CO}_2$  tensions can be indirectly compared by means of a graph by taking advantage of the fact that the  $\text{CO}_2$  tension of the sea water varies inversely with the pH when the alkaline reserve and temperature remain constant. The individual determinations are arranged in table 3 and in the graph (figure 2) in order of the alkaline reserve of the sea water as determined by the number of cc of 0.01 normal hydrochloric acid required to bring 100 cc of sea water to a pH of 4.2.

\*The data are arranged in the order of a low pH to a high pH of the sea water.

TABLE 3. *Containing the same data as table 1 but arranged in order from a low alkaline reserve of the sea water to a high alkaline reserve ††*

No. of Expt.	Acid or Base added	Alkaline reserve of water	pH of water	pH of blood plasma	O <sub>2</sub> in cc. per L.	T °C°
4	40 0a	1 93	5 30	7 18	5 64	15 75
8	10 0a	8 13	7 16	7 16	0 67	14 35
12	10 0a	8 54	7 51	7 12	5 90	15 60
11	10 0a	8 73	6 35	7 48	5 30	15 50
9	10 0a	8 86	5 60	6 80	2 00	15 40
10	10 0a	8 93	6 44	7 55	3 81	15 20
5	10 0a	9 08	7 25	7 20	5 65	16 10
2	5 0a	9 98	7 35	7 25	5 50	17 25
5		10 55	7 46	7 22	5 65	16 10
3		10 63	7 88	7 35	5 67	15 32*
3		10 63	7 88	7 35	5 67	15 32*
3		10 63	7 88	7 35	5 67	15 32*
3		10 63	7 88	7 07	5 67	15 32*
8		10 64	7 56	7 20	0 67	14 35
11		10 86	6 38	7 41	5 30	15 50
6		10 87	7 90	7 45	5 70	15 00*
6		10 87	7 90	7 45	5 70	15 00*
6		10 87	7 90	7 45	5 70	15 00*
6		10 87	7 90	7 45	5 70	15 00*
12		10 90	7 70	7 21	5 90	15 60
4		10 95	7 45	7 20	5 64	15 75
2		10 99	7 34	7 40	5 50	17 25
9		11 00	5 77	7 15	2 00	15 40
12	(?)	11 02	7 70	7 22	5 90	15 60
10		11 16	6 28	7 45	3 81	15 20
8	20 0b	11 12	7 84	7 18	0 67	14 35
5	20 0b	11 20	7 65	7 41	5 65	16 10
2	10 0b	11 34	7 44	7 44	5 50	17 25
5	30 0b	11 40	7 90	7 20	5 65	16 10
11	20 0b	11 52	6 20	7 60	5 30	15 50
9	20 0b	11 55	5 80	7 10	2 00	15 40
10	20 0b	11 73	6 25	7 47	3 81	15 20
11	30 0b	11 79	6 27	7 45	5 30	15 50
9	30 0b	11 79	5 83	7 35	2 00	15 40
12	30 0b	11 79	7 81	7 02	5 90	15 60
8	30 0b	11 95	7 85	7 20	0 67	14 35
10	30 0b	12 00	6 45	7 53	3 81	15 20
2	15 0b	12 07	7 49	7 47	5 50	17 25
4	40 0b	12 13	7 82	7 36	5 64	15 75
4	60 0b	12 63	7 89	7 29	5 64	15 75

When the alkaline reserves, i. e., the pH of the blood plasma after being brought into equilibrium with the CO<sub>2</sub> tension of the atmosphere, of two adjacent tests in table 3 are compared it is found that they vary inversely with the pH or better the CO<sub>2</sub> tension of the sea

\*Control experiments Fish were taken from live car in open water

†Experiments 1 and 7 were discarded Readings of the blood plasma were made after night by white light

‡The pH of the sea water shows relative carbon dioxide tensions when the alkaline reserve of the sea water is approximately the same. The same pH at the top and bottom of the table does not mean that the two have the same carbon dioxide tensions

water. The graph shows this point more emphatically. This relation of the alkaline reserve of the blood plasma to the  $\text{CO}_2$  tension of the sea water is surprisingly uniform, taking into account the methods used, the colorimetric method at best not being overly accurate.

When table 3 and the graph of figure 2 are observed in more detail, it is seen that the four tests of experiment 9 of table 1 all show an alkaline reserve of the blood plasma below expectation. This cannot be due to an error in making the tests since the variations in all four tests are in the same direction.\* These tests seem to indicate that there is an incomplete compensation in the blood plasma for high  $\text{CO}_2$  tension in the presence of low oxygen. In this experiment either the compensation was in the kind of base passed to the blood plasma or there was incomplete compensation or the compensation was in the blood and brought about by the introduction of an acid radical anion of a low ionization, and which was not dialyzable. The first is not tenable in view of the fact that if the base ion liberated into the blood plasma had been of a higher ionization this would have shown up in the dialyzed blood plasma with a high pH when brought into equilibrium with the  $\text{CO}_2$  tension of the atmosphere. There is some reason to believe that there was an incomplete compensation in the blood for the high  $\text{CO}_2$  tension of the medium. The fish became sluggish and remained at the top of the water throughout the duration of the experiment. Their gills became congested with blood. When a higher  $\text{CO}_2$  tension was used all four fish of the experiment died almost before the experiment could be started. The gills were congested with blood and their bodies were quite slimy. In experiment 9 all fish though sluggish as if affected with acidosis were alive at the end of the experiment of from 30 to 75 minutes duration. The compensation could not have been far from complete. In the higher animals a variation of perhaps 0.10 is fatal. When experiment 9 is compared with experiment 11 it is seen that there is a difference of 0.06 to 0.80 pH in the blood plasma when the  $\text{CO}_2$  tension is brought into equilibrium with that of the atmosphere. This difference in pH of the blood plasma of the two experiments is even still greater in view of the fact that the  $\text{CO}_2$  tension of the sea water in experiment 9 was higher than in experiment 11. The supposition that a nondialyzing acid anion radical of a lower ionizing acid than that of  $\text{H}_2\text{CO}_3$  is present finds support in the work of Christiansen, Douglas and Haldane (1914). Haldane (1922) states, "The first pair of experiments showed us that Ludwig's old suspicion was correct, and that at the same pressure of

\*The 7.35 pH for the blood plasma for the last test of this experiment is obviously too high as is shown by the other three tests.

$\text{CO}_2$  blood takes up considerably more  $\text{CO}_2$  in the absence than in the presence of oxygen. . . The effect may be due to saturated haemoglobin being a less alkaline substance than reduced haemoglobin, but is more probably dependent on the molecules of reduced haemoglobin having a much greater tendency to aggregate than those of saturated haemo-

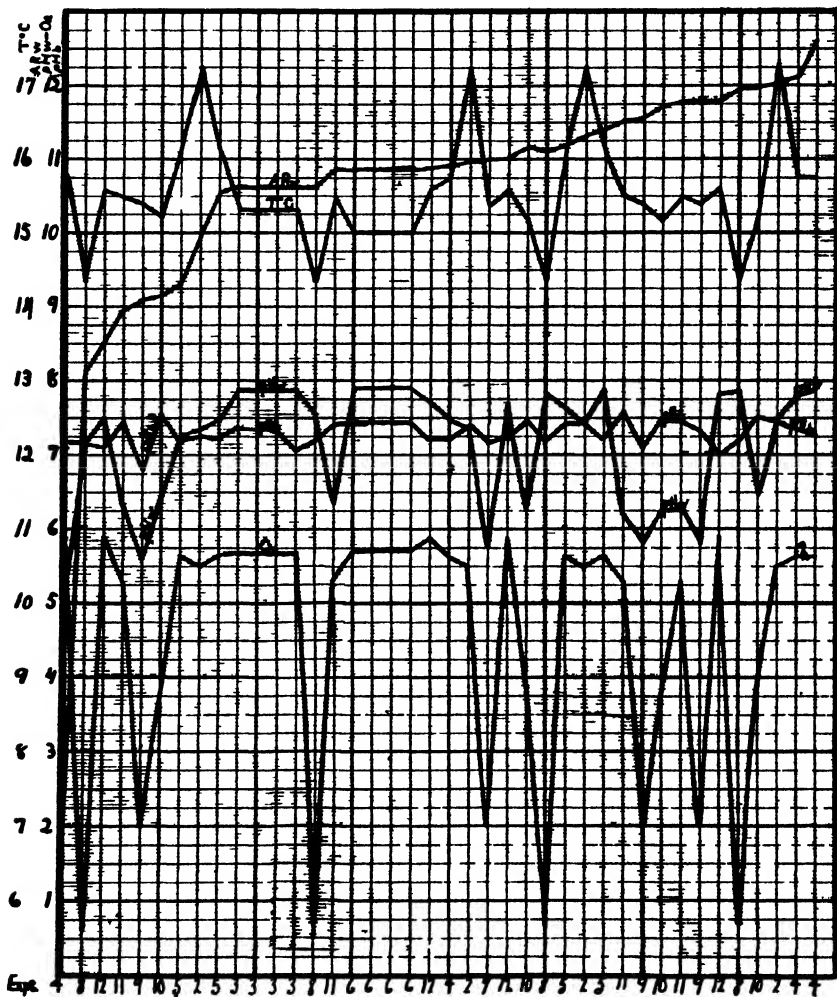
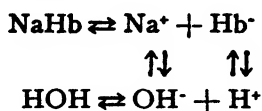


Fig. 2. A graphic representation of data given in table 3. Abscissae represent single tests of an experiment. Ordinates represent temperature, centigrade, ( $T^{\circ} \text{C}$ ) and alkaline reserve of the sea water, cc of 0.01 normal hydrochloric acid required to change 100 cc of sea water to a pH of 4.2 not corrected for salt error (ARw), the pH of the sea water (pHw), the pH of aerated dialyzed blood plasma (pHb) and the oxygen in cc per liter ( $\text{O}_2$ ).

globin". Van Slyke (1921) in speaking of the properties of the buffer action of blood states, "The other property is the change from a relatively weak acid to a relatively strong one which hemoglobin undergoes when it changes from the reduced to the oxidized form".

The reduced hemoglobin, "HHb", would obviously be a much weaker acid than  $\text{H}_2\text{CO}_3$  and if these assumptions are correct the actual H-ion of the whole blood at a given  $\text{CO}_2$  tension at low oxygen tension would be lowered in the presence of the Na-ion in accord with the following mass action:



Van Slyke (1921) states, "For oxyhemoglobin the value of the  $\text{pK}_{11}$ , and there of the pH of maximum buffer efficiency is about 7.16, and for the reduced hemoglobin about 7.3, as estimated from data of Haldane, of Joffe and Poulton, and of L. J. Henderson". That is, in the higher organisms the reduced hemoglobin has a tendency to raise the pH of the blood about 0.24 pH over that produced by the oxyhemoglobin.

In experiment 8 with very low oxygen and  $\text{CO}_2$  tensions the alkaline reserves of the blood plasma of the four fish behaved very differently from those in experiment 9 in being but slightly lower than expectation. The alkaline reserves of the blood plasmas of the fish in experiment 12 again behaved differently from either experiment 9 or 8.\* That is, the alkaline reserve of the blood plasma in each of the four fish with the exception of the one, the data† of which appears last in the table, are higher than expectation. This also holds when the comparison is made with the data of experiments 4 and 5. When experiments 3 and 6 are examined, which were intended as control experiments and which are in reality not exactly comparable with all other experiments here described since the environmental factors were at least not so rapidly varied, it is found that the alkaline reserves of the blood plasma were much higher than expectation even when compared with experiment 12. Experiments 3 and 6 will be mentioned

\*When experiment 8 with a low temperature (14.35 degrees C.) and experiment 3 with a high temperature (17.35 degrees C.) are compared with experiments at intermediate temperatures it is seen that the alkaline reserves of the blood plasma of the fish in experiment 8 are below expectation and those in experiment 3 are above expectation. Thus, there is an indication in these two experiments that high temperature increases the alkaline reserve of the blood plasma of fish and that low temperature has a tendency to lower the alkaline reserve.

†The 7.03 pH as given in the notes had a question mark after it which indicated that for some reason at the time the reading was taken the result was considered questionable.



again later. The  $\text{CO}_2$  tensions of these two control experiments were much lower as indicated by the pH and alkaline reserve of the water than any other experiment performed. The live car in which the fish were kept was massed with algae and was in direct sunlight, thus, the explanation for the very low  $\text{CO}_2$  tensions.

Haldane (1922) based upon work of A. V. Hill (1910) and especially the work of Douglas, Haldane and Haldane (1912) states that, "It seemed to us that the aggregation in protein solutions is a phenomenon of the same general nature as precipitation, the precipitate being, however, only formed in very small particles consisting of only two, three, or at any rate a few molecules. . . . .

"Thus reduced haemoglobin and oxyhaemoglobin molecules aggregate separately, and if we assume that reduced haemoglobin aggregates more readily than oxyhaemoglobin we can explain at once the distortion of the curve from the primary rectangular hyperbola obtained by Barcroft". Now if the view held by Haldane that the distortion of dissociation curve of hemoglobin from that of a rectangular hyperbola is due to the aggregation of the reduced hemoglobin over that of oxy-hemoglobin, and that aggregated reduced hemoglobin is more alkaline than the non-aggregated saturated hemoglobin, is correct, it follows from these experiments (experiments 9 and 8) that the reduced hemoglobin has a less tendency to aggregate at low  $\text{CO}_2$  tensions than at high  $\text{CO}_2$  tensions of the blood *in vivo*. Experiment 12 with a high oxygen content but with a low  $\text{CO}_2$  tension indicates that the oxy-hemoglobin as well as the reduced hemoglobin has a less tendency to aggregate in low than in high  $\text{CO}_2$  tensions. The view (Bayless 1920) that, "The effect of acids (*in distorting the rectangular hyperbola*) is the same as that of salts, but more marked" is in keeping with the present view of the physiologists. There is thus an effect of  $\text{CO}_2$  by its presence automatically, either through aggregation of protein molecules or by some other process, it being the same as that produced by salts, to change the reaction of the whole blood from a less alkaline to a more alkaline reaction, and thus assist in maintaining a more even reaction of the blood, i. e., to maintain a more nearly constant reaction of the blood as it passes from arterial to venous although  $\text{CO}_2$  has been added by the secretion of the tissues. The authors wish to state that this investigation was not undertaken for the purpose of solving some of the fundamental principles of physiology but rather for the purpose of determining the physiological factors underlying the choice of habitats of fishes and the migratory movements of migratory fishes. But notwithstanding the fact that the methods

employed were not in keeping with the more exact present day physiological technique the results indicate the validity of certain views held in regard to fundamental physiological principles.

A fish in sea water with a low oxygen content and a high  $\text{CO}_2$  tension would have a given  $\text{C}_\text{H}$  of the blood with a blood plasma having a smaller alkaline reserve than in sea water with a higher oxygen content. This observation does not have the objections that the blood is altered from that of the natural circulation as brought against the experiments of Christiansen, Douglas and Haldane by Haggard and Y. Henderson (1920). The blood was not only unaltered from that of the natural circulation but it was retained in the natural circulation itself. Through observations by one of us (Powers 1922) at Woods Hole it was found that the cunner (*Tautoglabrus adspersus* Walbaum) seemingly can be subjected with impunity to a very large range of  $\text{CO}_2$  tensions and oxygen contents of the sea water. With exact physiological laboratory methods this fish would make a laboratory animal par excellence for determining the exact effect of the reduced hemoglobin on the  $\text{C}_\text{H}$  of the blood and the  $\text{CO}_2$  capacity of the blood and the effects of variations in the  $\text{CO}_2$  tensions in the call of the alkali to or from the tissues by the blood and the Cl-anion to or from the hemoglobin by the blood plasma when the blood is unaltered and is in its natural circulation. From experiments by Powers and Altman, unpublished, there seemed to be some indications that alkali can be thrown into the sea water direct by the fish and perhaps again recalled.\*

In experiments 3 and 6 each of the four fish was taken from a live car which was kept in the open water at the station docks. With the exception of the last fish of experiment 3, the blood of which was dialyzed only ten minutes, the pH of the blood plasma of the fish of each experiment when brought into equilibrium with the  $\text{CO}_2$  tension of the atmosphere showed a striking uniformity. The color of the aerated blood plasma after the indicator had been added was so nearly alike in each case with the single exception mentioned that a difference could not be detected with the eye. These two control experiments showed two points: 1st. The same species of fish under the same environmental conditions have blood plasma of the same alkaline reserve; 2nd. When the conditions are changed in natural waters the alkaline reserve of the blood plasma is correspondingly changed.

In addition to the above two points, by an inspection of the graph

\*These experiments will not be published until the observations are conclusive.

(figure 2), it is obvious, as has already been pointed out, that the alkaline reserves of the blood plasma of the fish kept in the live car were much higher than that of experimental fish under more or less comparable conditions. The much higher alkaline reserve of the blood plasma perhaps cannot be explained entirely by the supposition that there is a less tendency for reduced hemoglobin to aggregate in low  $\text{CO}_2$  tension than in high  $\text{CO}_2$  tension, although these two experiments had the lowest  $\text{CO}_2$  tensions of the series, the live car being filled with algae which removed the  $\text{CO}_2$  from the water in the bright sunlight. This, then, puts the compensatory mechanism under two categories. First there seems to be a compensatory mechanism that is quite rapid which compensates more or less completely for a rapid change in the environmental conditions of the fish. The second can be placed in the category of acclimatization which is far less rapid. Thus the categories of compensations are not unlike those of man, i. e., a more rapid and perhaps a less complete compensation and a less rapid and perhaps a more complete compensation (Fitzgerald 1913 and 1914 and Y. Henderson 1920).

Thus, a fish, at least certain species of fishes, is or are apparently able to compensate very rapidly. The compensation is either not complete or is less advantageous physiologically than the less rapid compensation that we might put in the category of acclimatization.

#### DISCUSSION

It has been said (Reconstruction Problems 29, II. Salmon and Freshwater Fisheries, Ministry of Reconstruction, London, 1919), "As regards the habits and life history of the salmon, romance and fable for many years did duty for knowledge. . . . ."

"Within recent years, however, the salmon has been the object of closer and more intelligent study." Before the problem of fish migration can be solved with any degree of accuracy the individual ecology of the fish must be studied. Ecology is a branch of physiology. Thus, the physiology of the fish in relation to its environment must be studied. The problem is then both the study of the physiology of the fish and the physical and chemical factors of the environment as well as that of its relation to other organisms. This includes both laboratory and field observations. Experiments performed by Powers (1922, 1922a and 1923) indicate that the habits and habitats of fishes are at least to a certain extent tied up with the physiology of the respiration of the fish in relation to its environment. There seem to be essential differences between the migratory and the less migratory fishes. First

the less migratory fishes are able to extract oxygen from the sea water at lower oxygen tensions, and second this ability of the less migratory fishes is less affected by variation in the pH ( $\text{CO}_2$  tension) of the sea water than that of the more migratory fishes, and finally Krogh and Leitch (1919) have found that the hemoglobin of the blood of the *less migratory* fishes is better adapted to extract oxygen at low tensions than the *more migratory* fishes. Just in this connection we will quote at some length from Barcroft (1924).

"To take one point only, so far as we can see the conditions which decide the optimum hydrogen ion concentration are first, that the ratio of the rate of oxydation and reduction of blood should be most nicely balanced, and secondly, that alterations of hydrogen ion concentration which take place during pulmonary and tissue respiration should have their maximum effect upon the exchange of gases. Both these points seem to be gained by placing the hemoglobin in a medium whose hydrogen ion concentration is slightly greater than that of the plasma, as the inside of the corpuscle has been shown to be by the numerous researches . . . . .

"The physiological significance of the corpuscle as providing an independent medium for the hemoglobin may be illustrated by two, out of many examples which might be cited. The first has to do with the adaptation of hemoglobin to the different needs of different species, the second to the varying circumstances in which a single individual may find himself.

"The first I quote from Krogh (30) (*Krogh and Leitch 1919*) who drew attention to the different physiological conditions under which different species of fish live; some in the mud where the tension of oxygen is very low, others near the surface of the sea and of rivers where the water contains a considerable quantity of oxygen in solution.

"As Krogh saw, either the hemoglobin of these fish are not the same or being the same they are placed in different environments. Since there was no direct evidence in favor of the first alternative he attributed the differences in the dissociation or curves to variations in the environments furnished by the corpuscles.

"The second example is that of the adaptation which appears to make it possible for human beings to live and work in very rare atmospheres . . . . the hemoglobin is in a more alkaline medium."

When a corpuscle is to be considered from the standpoint of its adaptation for providing the needs of a fish or at least an adequate medium to meet the needs of a fish at least three other factors aside

from the variation in oxygen tension in modifying the environment of the corpuscle externally and perhaps in all cases internally as well must be taken into account. The fish lives in a world medium in which there is more or less continuous or spasmodic variation in each of  $\text{CO}_2$  tension, temperature, and contents in kinds, concentration and relative ratios of kinds and perhaps the pH of the medium more or less independent (physiologically) of any of the preceding. We have given abundant evidence in this and other papers by the senior author that the behavior and general physiological activities of organs associated with respiration are modified by variations in  $\text{CO}_2$  tensions of the medium. Wells (1914) has shown that freshwater fishes and Shelford and Powers (1915) have shown that marine fishes will react to very slight variations in temperature. Ward (1921) has observed that the Alaska red salmon always chooses a stream with the lower temperature when a choice of two streams is presented regardless of the fact as to whether or not the stream of the lower temperature is headed by a lake.\* Chidester (1920 and 1922) also suggests temperature as well as stream flow as a factor in fish migratory movements. Loeb and Wasteneys (1912), Loeb (1916) and others have shown that the permeability of tissues of even the gills of fishes is modified by the medium bathing them. One would be very much surprised after all the work showing the almost constant  $C_H$  of the circulating fluid of animals to find that the pH of the medium bathing the gills of fishes had absolutely no effect upon the physiological activity or activities of that organ.

The experiments of Jacobs (1920) in which he found that  $\text{CO}_2$  in solution was far more toxic to the tadpole of the toad (*Bufo americanis*) than other acids of the same hydrogen ion concentration are further evidence that the  $\text{CO}_2$  tension of the water is perhaps an important factor in the physiology of respiration of aquatic gill breathing vertebrates. As the authors see it one of the advantages gained by the invagination of the breathing apparatus of air breathing animals is that a membrane is kept moist and gas exchanges are able to take place by the process of osmosis. It is the  $\text{CO}_2$  tension of the alveolar air and not the pH of the fluid film covering the lining membrane of the alveolar cavities that affects or determines the  $\text{CO}_2$  tension of the blood. If this be true in man why should the pH as such of the water bathing the gills of a tadpole or that of a fish determine

\*The observation of Professor Ward on the Alaska red salmon is of special interest in that it shows that the red salmon does not choose a river when a choice of two rivers is presented because of its instinct for lake water (Jordan 1919). The red salmon is obviously responding to some factor or combination of factors other than lake water as such.

the  $\text{CO}_2$  tension of the blood of the tadpole or of the fish? The  $\text{CO}_2$  tension of the water should affect the  $\text{CO}_2$  tension of the blood of the tadpole or of the fish just as the  $\text{CO}_2$  tension of the alveolar air affects the  $\text{CO}_2$  tension of the blood of man. If the  $\text{CO}_2$  tension of the water is beyond that of the capacity of the tadpole or the fish to compensate, death will inevitably be the result. This is illustrated by an experiment performed in this series but not recorded. The  $\text{CO}_2$  tension was very high. The four fish were all dead almost before the experiment could be set up. However, there is no doubt but that the pH of the medium has its toxic effect as was shown by Jacobs' experiments. The pH of the fluid film bathing the alveolar cavities might have an influence but its effect is unknown.

Miss Jewell (1924) has found the blue gill, a fairly sensitive fish, living and reproducing in water with a pH of 4.4. She suggests acclimatization as a factor in that this fish is able to live and reproduce in water with such a low pH. It is obvious that this low pH as suggested "is due to a more strongly ionized acid than  $\text{H}_2\text{CO}_3$ ." It is possible or perhaps a fact that the blue gill would die very quickly in ordinary water brought to a pH even higher than 4.4 by  $\text{CO}_2$ . Shelford (1923) says "The optimum  $\text{CO}_2$  varies from 0 (pH 8.0) for bluegills to 6 cc per liter in water with about 200 parts per million alkalinity (pH 7.4-7.6) . . . . .". This is further evidence that the toxic effect of  $\text{CO}_2$ , at least a greater part, is due to causes other than the pH of the water.

The migratory fishes are able to sense out differences in the pH (perhaps the  $\text{CO}_2$  tension) of the sea water (Shelford and Powers 1915, Shelford 1918, 1919 and 1923 and Powers 1921). This ability seems less defined among the less migratory fishes (Powers 1921). Although more or less non-migratory fishes (the viviparous perch in these experiments and the rock fish, *Sabastodes deani* Starks, Powers 1922a) have been tested, the authors believe that a compensation in the blood for a variation in the  $\text{CO}_2$  tension and oxygen content of the medium is more effectively and rapidly brought about in the less migratory fishes than in the more migratory fishes. There is a time element. Y. Henderson (1920) in speaking of the readjusting of the alkaline reserve of the blood of man to variations in  $\text{CO}_2$  and oxygen pressures says, "It must be kept in mind, however, that these readjustments are matters of days or weeks". In the case of the viviparous perch and rock-fish it is a matter of minutes, not even hours; that is, the viviparous perch and rock-fish are able to bring about a readjustment in the alkaline reserve of the blood in a few minutes

where it requires days or weeks in the case of man. However, this rapid compensation may not be as nearly complete or physiologically advantageous as a second and less rapid readjustment which we have placed in a second category and designated as acclimatization.

In view of the above observations, the fact that the pH is lowered, i. e., the CO<sub>2</sub> tension of the sea water off shore is raised by the mixing of the CO<sub>2</sub> of the atmosphere during storms (Atkins 1922) and that ocean currents can be detected by differences in pH (Mayer 1919), presumably by differences in the CO<sub>2</sub> tension of the sea water, offers a plausible explanation as to why herring will quit the shoals after severe storms (Bertram 1897 and 1898) and will disappear almost exactly with the change in the current bathing the shore (Ekman 1880, Pettersson and Ekman 1890-91 and Pettersson 1894). Or it might even give a hint as to the mysterious reason why (Slosson 1924) "In 1424 the herring migrated in mass from the Baltic to the North Sea . . . ." Pettersson (1913) has shown that due to tidal variations at about the time that the herring ceased visiting the Baltic in large numbers the ocean currents had shifted so that different waters entered the Baltic. To quote from Pettersson (1909), "The tidal phenomenon in the underlying deep-water thus has the character of an oscillation which can have daily, monthly and annual periods.

"Whatever may be the main cause of these phenomena there can be no doubt of their influence upon the fish-life and fisheries of our seas. Already in 1877 G. Ekman discovered that the herring shoals vanished suddenly from the Swedish fjords and from the coast bank whenever the ice cold Baltic water accumulated there. The same observation was found to hold also in this winter. The greatest catches of herring of this year were made on the 1st-6th Feb. (50000 HL.) and on the 20-23 Feb. (35000 HL.) when the warm and salt deep water had its flow. In the ebb-periods the fishery was nil and ceased altogether about the 27th Feb." Pettersson (1894) also states, "We have observations which enable us to follow the departure of the herring from one fishing ground to another almost from day to day". In a communication April 6, 1920, Doctor Pettersson suggests that "Another consequence is that these waves cannot pass through the whole Kattegat Channel but are intercepted by submarine banks. Such submarine shoals are met with in the northern part of the Kattegat, Soatts of Gotenburg, whence the bottom channel from the North Sea shoals up from 200 meters to less than 100 or 80-70 meters. At the same place the channel becomes narrower. The effect of this is that the great boundary wave which the herring shoals follow in winter

from the North Sea there break up into smaller waves and rivulets. There also the herring-wandering stops. The herring shoals become so thickly concentrated that the fish which in summer time are caught by drift nets a mile wide in range in the open North Sea in winter time are caught by purse-seines in an area of a few square kilometers. The entire funnel-shaped canal of the Skagerak and Kattegat is like a cod-end of a trawl which collects the 'wandering' fishes (which according to my theory are by no means wandering but driven into our waters by the great internal movements of the undercurrent). Why should they 'wander' into this part of the sea? The zoologists, who believe in such spontaneous migrations, have two answers: 1st for propagation or 2nd for feeding purposes. Neither holds true. Our winter herring is spent; it has spawned before it reaches us, and it does not feed in our waters. There is no plankton to feed upon at that time of the year and the stomachs of the fish are empty. Why then should they travel so far from their living grounds led by a misguided instinct?"

The relations of the migratory movements of the herring to the internal movements of the sea during historic and prehistoric times are further discussed by Pettersson (1921).

The fact incidentally observed that the young fish born in the highly alkaline sea water experiments would all die almost immediately when placed in ordinary sea water might throw some light on races of fish visiting certain spawning grounds. It is common knowledge among fish culturists that young fish when hatched in an alkaline water cannot be rapidly transferred to an acid water, and vice versa. This phase of the problem needs investigation. The viviparous perch born in ordinary sea water, i. e., in the live car not only continued to live but were able to extract oxygen from the sea water down to 0.80 cc per liter at ordinary  $\text{CO}_2$  tension (15.55° C., 11.08 alkaline reserve and 7.61 pH).

For an excellent review of the present state of our knowledge in regard to fish migration the reader is referred to Chidester (1924).

It is not the contention of the authors that the  $\text{CO}_2$  tension of the water is the all important factor in fish migration as these experiments show that at least the viviparous perch is able to compensate rapidly for a variation in  $\text{CO}_2$  tension and oxygen content of the medium. However, it is the opinion of the authors that the  $\text{CO}_2$  tension is an important factor in the habits, habitats and migratory movements of fishes.



## SUMMARY

1. The alkaline reserve of the blood plasma of the blood of the viviparous perch (*Cymatogaster aggregatus* Gib.) is increased by a high CO<sub>2</sub> tension and decreased by a low CO<sub>2</sub> tension of the medium seemingly independent of the pH as such.

2. A low oxygen tension of the medium causes an increase in the alkaline reserve of the blood plasma of the fish due perhaps to the reduced hemoglobin being less acid than oxyhemoglobin. This tendency is much more marked in high CO<sub>2</sub> tensions of the medium than in low CO<sub>2</sub> tensions.

3. Perhaps high temperature raises the alkaline reserve of the blood plasma and low temperature lowers the alkaline reserve.

4. The compensatory mechanisms of the blood for changes in the environmental factors of the medium can perhaps be divided into two categories:

1st. A mechanism for a rapid compensation which is perhaps not complete or at least less advantageous physiologically than a

2nd. Mechanism which is less rapid and perhaps more nearly complete or at least more advantageous physiologically than the first. This second mechanism has been designated as acclimatization.

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## Resistance of Marine Animals of Different Ages

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One of the conditions which determines the success of a species in its particular habitat, is its resistance to the most extreme conditions which occur there. In each life cycle there is a most sensitive stage. This is usually a very young stage (Child 1915). After developmental changes are complete and the animal has the form of the adult, there are differences in resistance bearing definite relation to age, capacity for acclimatization, etc. A large number of tests of capacity to resist extreme conditions were made at the Puget Sound Biological Station between July 1 and July 30, 1918, on the common animals of the locality. Size was used as a criterion of age. Comparisons were made of different stages of 16 species, in higher temperature, increased acidity, reduced salinity, fresh water, stagnant water and strong light. The experiments were performed in standing water which varied with air temperature and ranged from 11° C. at night to 20° C. during the day. They were all combinations of high temperature with the factor noted, as the sea water from which they were taken is usually about 11° C. From this large series of experiments a few typical ones are shown here.

Experiments were made to test the resistance to reduced salinity. Ordinary city drinking water, piped from a lake, was used (table 1).

TABLE 1. *Resistance to fresh water.*

Species	No. of Animals	Size in mm	Survival time in minutes
Strongylocentrotus dorbachiensis (Green Sea Urchin)	1	6	35
	1	15	125
	1	43	140
	1	93	310
Ditto	1	31	205
	2	43	701
Achmaea pelta (Limpet)	1	18	29
	2	25	51
Hyas lyratus (Crab)	1	37	50
	1	75.3	53

It will be noted from the list above that the smaller animals die first, which is the general rule for marine animals in fresh water. This may result from the decrease in surface in proportion to the volume in the larger animals.

In the case of young isopods (*Pentidotia wosnessenskii*) taken

from the brood pouch of the parent, the young when first removed lived 107 minutes against 159 minutes for the adult. However the survival time for the young decreased rapidly with the increase in their stay in salt water, after being removed from the brood pouch and before being put into the fresh water.

When animals are dropped into temperatures that kill in an hour or less, resistance to temperature follows the same rule as resistance to fresh water. For example a small species of jelly fish (*Thaumantias cellularia* Haeckel) was tried. When a large individual (diameter about 10 cm) and a small one (diameter about 6 cm) were dropped directly into sea water at 27° C., the smaller one died first. When the adult and smaller size were slowly warmed, the smaller one died after 22 minutes at a temperature of 27.5°C., showing a greater capacity for acclimitization in the smaller individual. This result was typical.

Experiments were made to test resistance to increased hydrogen-ion concentration. In these 10 cc N/20 H<sub>2</sub>SO<sub>4</sub> was used to 100 cc of sea water (table 2).

TABLE 2. *Resistance to acidity.*

Species	Diameter in mm	Survival time in hours
Strongylocentrotus drobachiensis (Green sea urchin)	5	23
	38	169
	127	53
Ditto	16	24
	50	160
	140	29

These experiments indicate that the older individuals are less resistant to acidity than the younger, i. e., in medical terms, they have a smaller alkaline reserve, as has been found for old men and old dogs.

Experiments to test resistance to increased hydrogen-ion concentration in fresh water were made. In two of these experiments the results are the same as with fresh water alone, due perhaps to the slight acidity and the high resistance of the two species. The viviparous perch however shows a weakened condition in the breeding adult and a remarkably high resistance for the newly born young. The last is not easily explained but may follow from an acid condition in the uterus. In the tabulated results (table 3) the figures in the left hand column show the number of cc of N/20 H<sub>2</sub>SO<sub>4</sub> added to 100 cc of fresh water.

TABLE 3. *Resistance to acidity in fresh water.*

Species	Size	Survival time
Viviparous perch 2 cc	165 mm (with young)	25 min.
	100 mm	38 min.
	Just born	70 min.
Green isopod 2.5 cc	Adult	116 hrs.
	Young from brood pouch	19 hrs.
Oligocottus sp. (Cottid, Bull Head)	32 mm	94 min.
	63 mm	176 min.
	215 mm	203 min.

Standing sea water, in which the acidity becomes greater as the oxygen is consumed, was then tried (table 4).

TABLE 4. *Resistance of purple shore crabs to stagnant sea water.*

Condition of water at end of 5 days	Diameter in mm	Survival time in hours
O, 0.602 cc per liter.....	Large, 100	26
CO <sub>2</sub> , 6.23 cc per liter.....	Medium, 63	312
N/100 iodine absorbed.....	Small, 25	171

This was one of the few cases in which the largest died sooner than the smallest, perhaps due to the lowered alkaline reserve.

It is evident that the youngest animals are the least resistant to fatal conditions, but possess the greater capacity to acclimate. In no case, however, has it been indicated that the old individuals are ever less resistant than some of the earlier stages (Child, 1915, pp. 412-416), except in cases in which high acidity was used and an old age lowering of alkaline reserve may be assumed. Here, and in the case of most viviparous animals, the resistance of the parent at the time of birth may fall as low, if not below that of the young.

This work was done at the Puget Sound Biological Station, under the direction of Dr. V. E. Shelford of the University of Illinois, whose kind assistance I wish to acknowledge.

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## Influence of Hydrogen Ion Concentration, Salinity and Oxygen Upon the Rheotaxis of Some Marine Fishes

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These experiments were performed in 1922, chiefly with young sockeye salmon (*Oncorhynchus nerka* Walb.) averaging 6.75 cm in length and 1.53 g in weight, collected July 3; herring (*Clupea pallasii* C. & V.); and tom cod (*Microgadus proximus* Gir.). All were seined near the Puget Sound Biological Station and kept in a live box. The sea water came from a tank filled daily. The fresh water was piped from a lake; its temperature averaged 13.8° C. The experiments were conducted in an Allee straight current box (Shelford 1914). The pH was controlled by adding Na<sub>2</sub>CO<sub>3</sub> or HCl. Five fish were used in most cases. One minute was allowed for adjustment, then 10 readings were taken 10 seconds apart. After each test normal sea water was turned into the box before a new experiment was run.

To observe the effect of reduced salinity and reduced oxygen content upon salmon, the flow was regulated at 8 cm per second and the average of 6 tests was recorded (table 1). There is a break in the sequence of decreasing percentages; but the significant thing is the low positive rheotaxis in fresh water.

TABLE 1. *Rheotaxis of young salmon.*

Current	Temperature	pH	Positive	Negative
Normal sea water.....	10.8	7.8	99%	1%
½ Fresh water.....	....	7.6	90%	10%
¼ Fresh water.....	....	7.4	96%	4%
Fresh water.....	13.8	7.2	46%	54%

At first the importance of reduced oxygen was not recognized. The sea water averaged about 4.5 cc per liter; the fresh water about 2.95 cc. One salmon was then available, but it showed 100% positive reaction to normal sea water, 40% positive to fresh water direct from the tap, and 80% positive to fresh water aerated until the oxygen content was about 5.1 cc per liter. This showed that oxygen is probably an important factor in determining the rheotaxis of salmon.

To study the effect of higher hydrogen ion concentration upon salmon, a small stream of HCl was siphoned into the current, and the fish were observed in varying degrees of acidity. A comparison with the salinity series shows that when the pH of the sea water was reduced to 7.2, the average pH of the fresh water, the rheotaxis of the salmon was 100% positive; and even when the pH was reduced to 6.0, although the fish showed great distress, their reaction was more positive than in freshwater.

In August, 1920, Dr. V. E. Shelford determined the pH of several Pacific Coast streams. None of the streams showed a pH lower than 6.5, except a small mountain stream which was 6.4; Aug. 6, Nooksack River, pH 6.5; Aug. 5, Fraser River, 6.9; Aug. 7, Columbia River, near Vancouver, 1 meter below surface, 6.5, and at surface, 7.1.

Positive rheotaxis of salmon in sea water plus HCl was as follows: pH 7.6, 100%; 7.4, 100%; 7.2, 100%; 7.0, 96.2%; 6.6, 95%; 6.0, 57.5%. There were no indefinite responses.

From a comparison of the percentages in the salinity series with those of the higher H ion concentration and the river readings, it appears that the higher H ion concentration of a salmon stream would have a much smaller effect upon the rheotaxis of the fish than oxygen content or reduced salinity.

The pH was then raised by introducing a solution of  $\text{Na}_2\text{CO}_3$ . At 8.2 there was a slight negative response, but no change at 8.0; since few waters which the fish will inhabit have a higher pH than this, and since the effect was so slight, the series was not continued.

About 16 rheotactic experiments were performed with young herring. The herring were very erratic in their movements, swimming up and down stream a great deal, so that the periodic readings do not represent clearly their great activity. Possibly they were disturbed by the limited space in the current box, although they were smaller than the salmon. Further experiments might have discovered a current of a different velocity to be the optimum for them. The results in the different solutions show very irregular decreases in the positive reaction but along lines similar to those of the salmon.

The rheotaxis of three different groups of young tom cod of about the same size as the salmon was tested. The cod responded more positively in all the solutions. The strong positive response in aerated water seems to indicate that oxygen content is a more important factor in their rheotaxis than is salinity (table 2).

TABLE 2. *Showing the rheotaxis of young cod.*

Solutions	O <sub>2</sub>	Temperature	pH	Positive	Negative
Normal sea water.....	4.5	10.8	7.8	100%	0%
½ Fresh water.....	...	....	7.6	100%	0%
¼ Fresh water.....	...	....	7.4	100%	0%
Fresh water.....	3.21	13.5	7.0	72%	28%
Aerated fresh water.....	5.08	....	7.0	98%	2%

## CONCLUSIONS

The experiments show that the rheotaxis of all the fish experimented with is affected definitely by various factors. The rheotaxis of the cod was more positive than that of the other fish, in all the solutions used. Reduced oxygen content seems to be a much stronger controlling factor than the loss of salinity, in causing a negative reaction.

The rheotaxis of the salmon is affected by increased hydrogen ion concentration and to a slight extent by reduced hydrogen ion concentration. There is a strong negative response under reduced oxygen content and reduced salinity. Further experiments would be necessary to determine the relative importance of these two factors. If the results are typical, the oxygen content is the more important, as is the case with the cod. Gilbert (1917) found that the Fraser River sockeye salmon predominantly return to the particular part of the river basin in which they were reared as fingerlings. If the modification of rheotaxis is constant in young fish, as it was in those tried, certain physiological changes must take place in young salmon before they reverse their rheotactic response and swim up fresh water streams. Greene (1909) found that it sometimes takes 40 days for salmon to pass through the brackish waters on their way up stream. This may be a period of physiological change.

Acknowledgment is made to Dr. V. E. Shelford who directed the work, and to Professor T. C. D. Kincaid who identified the salmon.

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## Observations on the early Development of *Argobuccinum Oregonense*

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It is to the interest of investigation that a constant search be maintained for forms that, by their peculiarities, lend themselves well to particular types of experimentation. There is a great opportunity and need at the Puget Sound Biological Station for work of this kind, for, with the great abundance of material at hand for study, there is a scarcity of records concerning the habits, structures and developmental relations of the various forms.

It was with this need in mind that a study of the development of *Argobuccinum oregonense* was undertaken. As the work progressed interest developed in the behavior of the yolk lobe, the importance of which as a possible "organ forming portion" of the egg, has been considered in related forms by Wilson (1904), Crampton (1896), and Conklin (1905).

This study was made at the Puget Sound Biological Station during the summer of 1922 under the guidance of Dr. B. M. Allen of the University of Kansas. This occasion is taken to express an appreciation of the opportunities afforded for this work by the Station and to extend thanks to Dr. Allen for help and encouragement given at various times as the work progressed.

### PREPARATION OF MATERIALS

Both living and preserved materials were used for this study. During the month of August eggs were laid in abundance by the individuals in the live boxes at the Station, and it was possible to get all desired stages in the development of the material. All of the drawings have been made from stained material.

The eggs to be stained were removed from the capsule and washed until entirely free from the gelatinous substance. In all cases Bouin's fluid was used as a fixing agent. After fixing, the eggs were washed thoroughly in 70% alcohol. For use as a stain Delafield's haematoxylin was diluted 1 to 6 with distilled water and acidulated by the addition of one drop of hydrochloric acid to each 100 cc of the dilution. The eggs were placed in this from 30% alcohol and left for 25 to 30 minutes. After dehydration and clearing they were mounted in balsam under a cover slip beneath which small pieces of glass were

placed to prevent the crushing of the egg. It was found that the success in making a preparation depended to a considerable extent upon the clearing. Prepared slides that are a month old are superior to new preparations.

### Eggs

*Argobuccinum oregonense* Redfield, is a very common mollusk in the Puget Sound region. Usually it is to be found in dredgings obtained at depths from low tide to 110 meters.

Eggs were found in abundance during June, July and August. The egg cases are deposited usually on the surface of large rocks on reefs where there is an abundant change of water and at a level where they are barely exposed above the surface of the water at minus tides. Egg masses were obtained, however, attached to shells and rocks taken from a depth of 20 meters. During the months of June, July and August 10 individuals deposited eggs in the live boxes at the Station.

Eggs are deposited in rectangular capsules each about  $6 \times 6 \times 3$  mm. The capsule wall is tough and somewhat transparent. The eggs within are embedded in a gelatinous substance in such a way that they do not come directly in contact with one another. The importance of the capsule and the arrangement within is indicated by the fact that the eggs do not develop normally when removed. The fact that all eggs within a capsule develop, and that the development is remarkably uniform, may be due to conditions supplied by the capsule.

A single capsule contains from 1600 to 2000 eggs. In one instance a single individual produced in one place 125 capsules. It thus seems that a single individual may produce about 200,000 to 250,000 eggs. An individual was observed to occupy a period of 14 days in laying a mass of eggs. This individual was still attached to these egg cases when this study was brought to a close on August 20th. Individuals have been found attached to egg masses when all of the embryos contained in the capsule were beyond the trochophore stage.

In the earliest material obtainable for this study some polarization existed in the egg. Figure 1 shows the condition of the egg previous to the maturation divisions. At this stage of development the egg is about 0.95 mm in diameter. It is too opaque, due to the densely packed yolk spherules, to show much of its structure. A clear protoplasmic area at one end indicates the future maturation pole. In stained material that has undergone a considerable amount of clearing the germinal vesicle has been seen as in figure 1 in this clear cytoplasmic area. This is the condition of the eggs obtained from a cap-

sule shortly after it was extruded from the female. It has been impossible in this study to determine whether or not there is an absence of polarization in the earlier stages of the development of the egg.

During maturation some further indications of polarization become evident. These changes in the egg are discussed in another part of this paper.

#### MATURATION, FERTILIZATION AND CYTOPLASMIC DIFFERENTIATIONS

In the earliest material obtained, 5-7 hours elapsed before the appearance of the first polar body. During all of this time the germinal vesicle lies toward the animal pole of the egg in the protoplasmic area which at this time is devoid of the large yolk spherules which are so densely packed in the other portions of the egg (Fig. 1). Figure 2 shows the approach to the first maturation division. Here the egg wall at the animal pole dips inward to form a cup-shaped depression. This depression is present during the time that the first maturation spindle is in its formation and during the time that this spindle undergoes a rotation of 90 degrees (Fig. 3). During this time the male pronucleus has been observed to be present at the periphery of the egg (Figs. 2, 3). This indicates the possibility that the entrance of the sperm initiates the process of maturation in *Argobuccinum*. In the later stages of the development of this first maturation spindle the cup-shaped cavity at the animal pole of the egg becomes shallower as the spindle moves toward the surface of the egg. Finally, in the last stages of the division, the cavity disappears and the egg wall at the animal pole bulges outward (Fig. 4), and the first polar body is cut off.

The second polar body has been observed to be formed in the living material in 3-5 hours after the disappearance of the first polar body. Figure 5 shows this division to occur in the usual way.

The chromosomes remaining in the ovum after the formation of the second polar body are reformed into a reticular nucleus smaller than the original oocyte nucleus. This nucleus moves toward the cytoplasmic center of the ovum where it remains during the approach of the male pronucleus (Fig. 6).

During the preliminary maturation stages and at the union of the male and female pronuclei there occur some very noticeable changes in the distribution of cytoplasm within the egg of *Argobuccinum*. Such cytoplasmic movements within the egg have been looked upon by some as being of very profound significance in connection with the establishment of organ forming regions of the cytoplasm. (Crampton



1896, Wilson 1903, 1904, Yatsu 1904, Zeleny 1904, Conklin 1898, 1905). It has been shown by Wilson (1904) in *Dentalium* and by Crampton (1896) in *Ilyanassa* that certain regions formed in the egg as a result of protoplasmic movements are "organ forming." The view that such localized areas of the cytoplasm come into existence from a process of true progressive development is supported by experimental work, especially that of Wilson (1903), Yatsu (1904), and Zeleny (1904), on the eggs of *Cerebratulus*. Conklin (1905) has called attention to the possibility that these developments within the egg of localized 'organ forming' areas may be brought about by the influences of the nuclear mechanism within the egg. He states, "However in the fact that large quantities of 'nuclear sap' containing dissolved oxychromatin escape into the cell body at each mitosis (v. Conklin, 1922) and that the nuclear substances then contribute to the forming of specific organ forming substances of the cytoplasm we see a possible means of harmonizing the facts of cytoplasmic organization with the nuclear inheritance theory".

In *Argobuccinum* the relationships in time which have been observed to exist between the occurrences of cytoplasmic differentiations in the egg and certain events such as the entrance of the sperm, the disorganization of the germinal vesicle, and the union of the male and female pronuclei, suggest the possibility of such a nuclear-cytoplasmic relationship as mentioned by Conklin. It has been the aim in this portion of the study to describe as far as possible these cytoplasmic movements and differentiations as they occur in the eggs of *Argobuccinum*, and to determine to what extent these events are simultaneous with the outstanding occurrences that are noticeable in the nuclear mechanism of the egg during maturation and fertilization.

Soon after the egg has been extruded and before there are any changes in the germinal vesicle preparatory to maturation there is visible evidence of cytoplasmic polarization (Fig. 1). There is, as has already been pointed out, a clear protoplasmic area at the future maturation pole in which the germinal vesicle may be seen. It has been impossible to determine in this study whether or not this condition of differentiation exists earlier in the development of the egg.

Some additional changes in the cytoplasmic distribution occur during the first maturation division. A clear cytoplasmic zone appears at the vegetal pole of the egg. In the region of this zone there is a slight bulging of the egg wall as is shown in figures 3, 4 and 5. This clear polar zone exists throughout all of the phases of the two maturation divisions and is easily observed in the living material. This

condition is uniformly present in all of the eggs of a capsule when the eggs are in this state of development. The fact that this clear polar zone is not present at the vegetal pole in those eggs in which the germinal vesicle is present, indicates that this change in the cytoplasmic arrangement may be associated with the disorganization of the germinal vesicle which occurs in advance of the first maturation division.

About the time of the union of the male and female pronuclei another change in cytoplasmic distribution is very evident. The large polar lobe protrudes (Fig. 6). The clear cytoplasm of what has been referred to above as the lower polar zone passes into this large lobe or protrusion. After the protrusion of this polar lobe the polar zone is no longer to be seen at the vegetal pole (Figs. 6, 8). This polar lobe appeared to be filled entirely with clear cytoplasmic substance. Yolk spherules and granules which are so abundant in the central portion of the egg do not enter the lobe. It is thus improper, as has been pointed out by Zeleny (1904), to designate the protrusion as the "yolk lobe", although some writers have used this name for it.

There is some evidence to indicate that the protrusion of the polar lobe occurs at the time of the union of the male and the female pronuclei. The polar lobe does not protrude during any of the maturation stages (Figs. 1, 2, 3, 4, 5). It has been difficult on account of the opaque condition of the central portion of the egg to find many instances in the stained material which show the union of the pronuclei. In every instance found in which the pronuclei are uniting the polar lobe is protruded as in figure 6. The polar lobe is uniformly present in all of the stages studied in which the first cleavage spindle is seen (Fig. 7). This evidence seems sufficient to justify the belief that there is some relation between the union of the pronuclei and the protrusion of the polar lobe in *Argobuccinum*. This relationship is significant especially in view of the fact that the polar lobe of closely related forms has been found to be a very definite organ forming region (Wilson 1904).

The polar lobe of *Argobuccinum* remains large and stationary, and was not observed to be withdrawn and protruded at intervals as described by Crampton in *Ilyanassa*.

#### FORMATION AND DIVISION OF THE MICROMERES AND FATE OF THE POLAR LOBE

At the first cleavage the lobe remains a part of cell CD (Fig. 8). At the second cleavage the lobe becomes a part of cell D (Fig. 9). Figure 11 shows the position of the polar lobe at the vegetal pole during the time that the first set of micromeres is forming. At this stage

he lobe is still quite prominent. Figure 14 shows an absence of the prominent polar lobe attached to cell D. In this stage the second quartet of micromeres are present and the first set of micromeres are dividing to form the turret cells. It would thus appear that the polar lobe does not show up prominently after the formation of the second quartet of micromeres.

In the third cleavage 4 micromeres are produced from the animal poles of the macromeres (Fig. 10). These micromeres are composed of clear protoplasmic substance and do not receive any of the yolk spherules of the macromeres. The direction of the spindles is seen to be to the right indicating a dextrotropic division. In figure 10 it is seen that the process of division in cell C is most complete while the cells B, A, and D show progressively earlier stages of development. Conklin has pointed out the significance of this in connection with spiral cleavage in *Crepidula*.

Figure 12 shows the next stage in development. The second quartet of micromeres are here seen to be given off in an anti-clockwise direction. Figure 13 shows these micromeres completely developed.

The first quartet micromeres now divide laetotropically (Fig. 14). This division is unequal. The smaller daughter cells  $1a^2$ ,  $1b^2$ ,  $1c^2$ ,  $1d^2$  are the turret cells; the larger of the daughter cells,  $1a^1$ ,  $1b^1$ ,  $1c^1$ , and  $1d^1$ , are now known as apical cells.

In *Argobuccinum* the process of the formation of the third quartet of micromeres by a dextrotropic division and the division of the second quartet micromere cells occur at about the same time. The first mentioned process is slightly in advance (Figs. 15, 16). When this is complete there are present 24 cells; these consist of 4 centrally located apical cells, 4 smaller turret cells, 12 belt cells of which 8 come from the divisions of the first quartet cells and 4 are the second quartet cells, and 4 macromeres.

The condition which next appears in development is indicated in figures 16 and 17. The second division is here occurring in the first quartet cells. This division is dextrotropic. Figure 17 shows a spindle formation in one of the macromeres which is for the production of the mesentoblast (4d) cell as it has been called by Conklin. These conditions when complete result in the formation of the 29 cell stage.

#### SUMMARY

The early cleavages of *Argobuccinum* described in this paper differ only in minor details from the development of *Crepidula* described by Conklin.

The polar lobe (Figs. 6, 7, 8) in the egg of *Argobuccinum* is very prominent. It is entirely made up of the clear cytoplasmic part of the egg and is devoid of yolk spherules which are so abundant in the central portion of the egg.

In related forms (Wilson 1904) the polar lobe has been demonstrated to be an "organ forming" region of cytoplasm. It is probable that the polar lobe in *Argobuccinum* may play a similar role.

In this study it has been determined that the protrusion of the polar lobe in *Argobuccinum* is related in time to the union of the male and female pronuclei. This relationship is significant especially in view of the possible relation of the nuclear mechanism of the egg to the cytoplasmic changes and differentiations that may occur in many eggs before cleavage.

The polar lobe of *Argobuccinum* is not withdrawn and protruded at intervals as has been described by Crampton for *Ilyanassa*.

The polar zone (Figs. 3, 4, 5) is a clear cytoplasmic area which appears at the vegetal pole of the egg and persists until the time of the protrusion of the polar lobe (Fig. 6). This polar zone is not present in the eggs of *Argobuccinum* in their earlier stages. It is uniformly present during the maturation stages and until the time of the protrusion of the polar lobe. There are indications that this differentiation of the polar zone is related in time to the disorganization of the germinal vesicle preparatory to maturation.

It is very probable that the entrance of the sperm in *Argobuccinum* initiates the process of maturation.

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## PLATE 34

Drawings with camera lucida from stained preparations.  $\times 310$ .

FIG. 1. Ovum previous to the formation of the first maturation spindle.

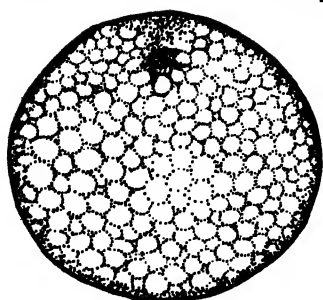
FIG. 2. Ovum previous to the formation of the first maturation spindle. The male pronucleus is seen near the vegetal pole.

FIG. 3. First maturation spindle showing evidence of rotation. The male pronucleus is present at the side of the egg. There is a slight bulging at the vegetal pole where the clear protoplasmic zone is located.

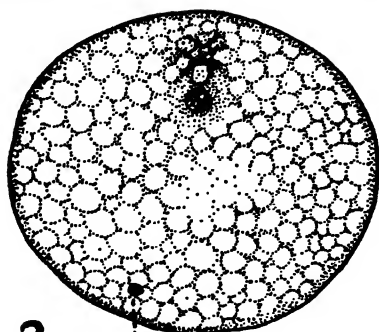
FIG. 4. Telophase of the first maturation division. The egg wall bulges out at the animal pole preparatory to the cutting off of the first polar body. The male pronucleus is in evidence.

FIG. 5. Anaphase of the second maturation division.

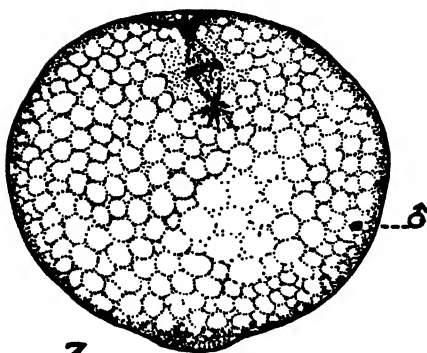
FIG. 6. Union of the male and female pronuclei and the formation of the polar lobe at the vegetal pole.



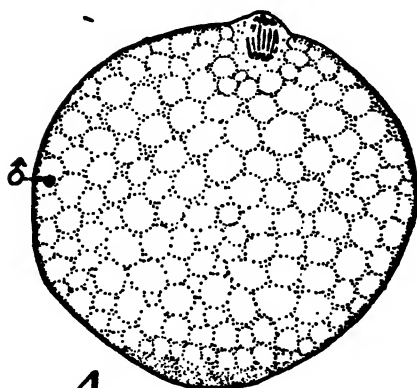
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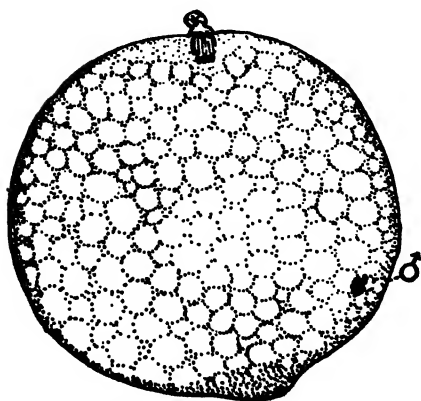
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 $\sigma$ 

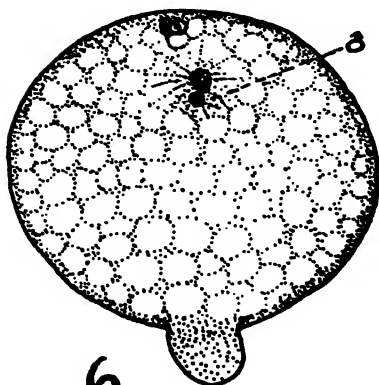
3



4

 $\delta$  $\delta$ 

5

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6

 $\delta$

## PLATE 35

Drawings with camera lucida from stained preparations.  $\times 310$ .

FIG. 7. First cleavage spindle.

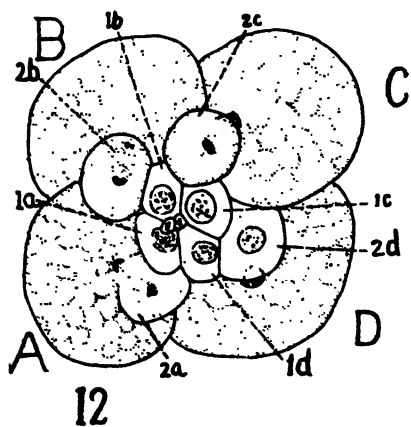
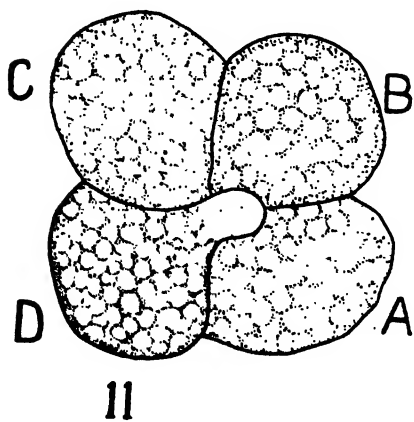
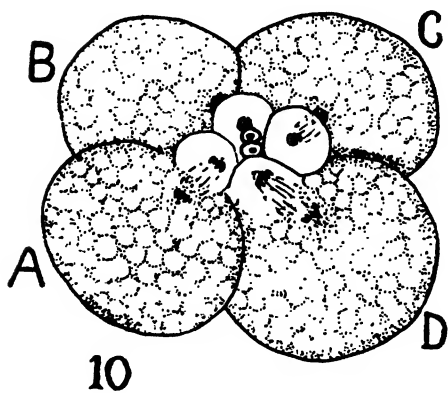
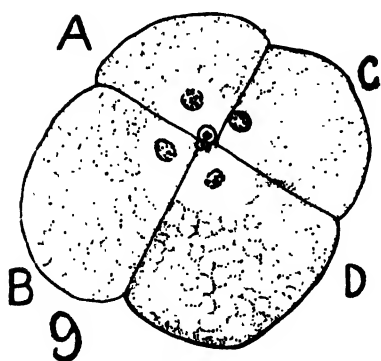
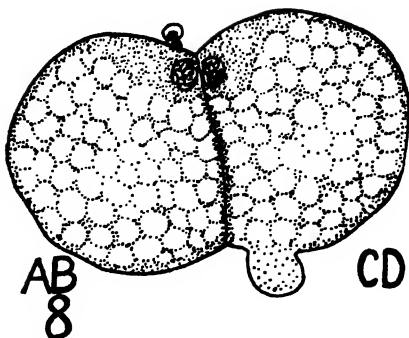
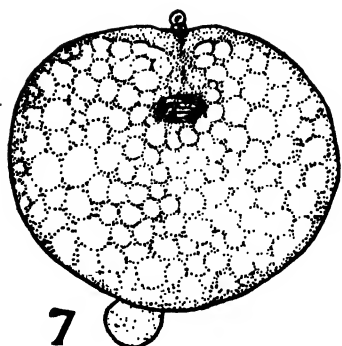
FIG. 8. Two cell stage. The polar lobe has become a part of CD.

FIG. 9. Four cell stage from animal pole.

FIG. 10. Formation of the first set of micromeres by dextrotropic divisions.

FIG. 11. Eight cell stage from the vegetal pole showing the position of the polar lobe.

FIG. 12. Formation of the second quartet of micromeres by a laeotropic division.





## PLATE 36

Drawings with camera lucida from stained preparations.  $\times 310$ .

FIG. 13. Twelve cell stage.

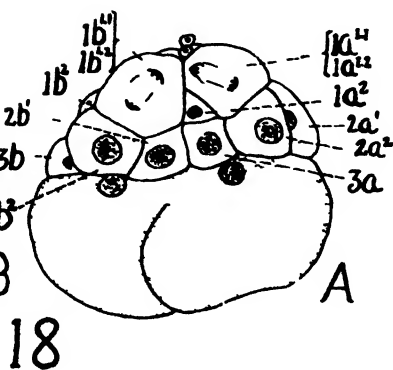
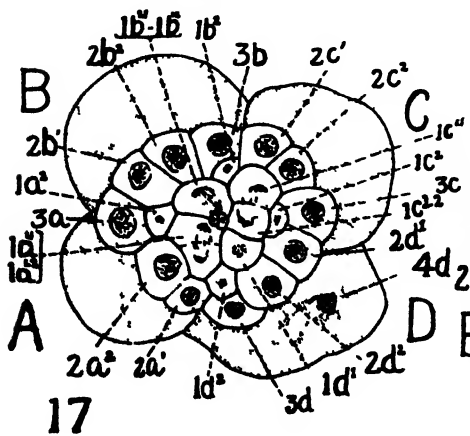
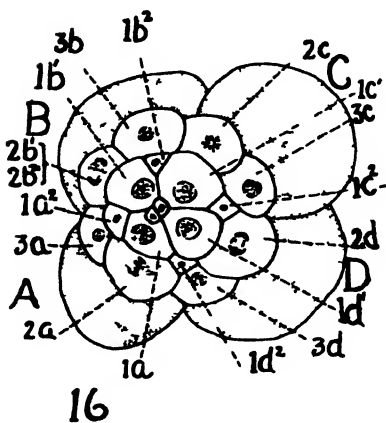
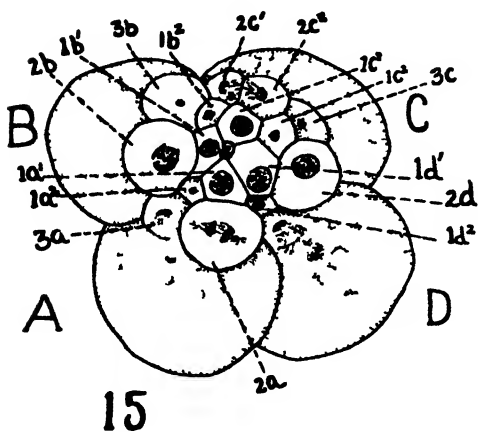
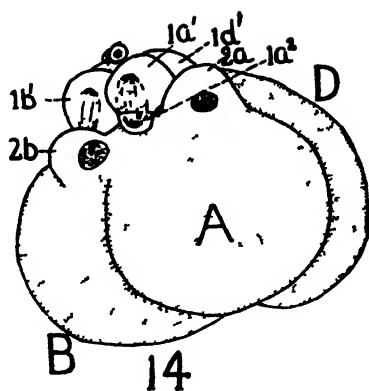
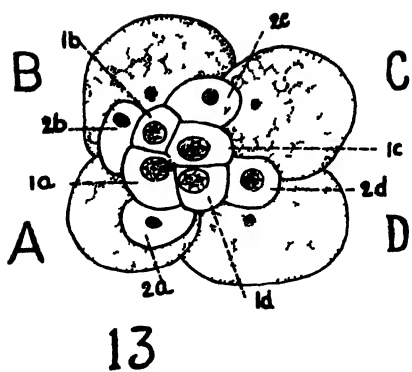
FIG. 14. Division of the first quartet micromeres to form the turret cells.

FIG. 15. Formation of the third quartet of micromeres by dextrotropic divisions. Formations of the spindles in the second quartet micromere cells. The division of the first quartet micromeres into the formation of the turret cells is complete.

FIG. 16. The formation of the third quartet of micromeres completed. The division of the second quartet of micromeres is in progress.

FIG. 17. Approach to 20 cell stage. The division of the second quartet of micromeres is complete. The apical cells are dividing. A spindle is formed in cell D for the formation of the mesoblast cell.

FIG. 18. Side view of 28 or 29 cell stage.





# Development of Certain Puget Sound Hydroids and Medusae

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## INTRODUCTION

The life cycle of the hydromedusae of American waters has received scant attention. This is especially true of the Pacific, where a great variety of forms awaits a recorder of the cyclic phenomena which these interesting animals manifest. The Puget Sound region, in general, and the vicinity of Friday Harbor, Washington, in particular, is swarming with many genera of medusae during most of the year.

The problem undertaken was to connect some of the free swimming medusae with their hydroid colonies. The work was done at the laboratories of the Puget Sound Biological Station, at Friday Harbor, Washington, from June 28 to August 10, 1922.

I wish here to acknowledge with thanks the suggestions of Drs. W. C. Allee, B. M. Allen, T. C. Frye, H. H. Newman, C. V. Taylor, H. B. Torrey and Professor Trevor Kincaid. The last named was especially helpful in identifying several species used in connection with the work.

Since systematists usually place the medusae in different genera from the hydroid colonies from which they arise, the literature of the subject is more or less in confusion and hard to follow. Synonyms are legion. According to Mayer (1910) the medusa genus *Stomotoca* is produced by the hydroid genus *Perigonimus*; the medusa genus *Phialidium*, by the hydroid genus *Clytia*; the medusa genus *Aequorea*, by the hydroid genus *Campanulina*. Fraser (1914), who has made a late and extensive classification of Puget Sound hydroids, confirms Mayer.

## METHOD

About 100 medusae of a given species were carefully washed in clear strained seawater in order to free them from debris. These were then allowed to spawn in a glass aquarium about 10 inches in diameter. After a copious number of eggs and sperms had been deposited the medusae were removed from the aquarium and fertilization allowed

to take place. Embryos were killed in all stages of cleavage, in blastula, in planula and in affixed hydroid stages. These were then preserved in 10% formaldehyde. The aquaria were kept at a low temperature by being partly immersed in running cold water. When the free swimming planula stage was reached, glass slides were suspended in the water to serve, along with the sides of the aquaria, as a substratum for the attachment of the planulae. Care was taken to have clean seawater, free from debris, as the latter tends to accumulate about the hydranths of the young colonies and to cause an abnormal condition leading to death.

#### OBSERVATIONS

*Phialidium gregarium* Haeckel (Figs. 1-6) was observed from June 30 to July 20, 1922.

One hundred sixty medusae of *P. gregarium* were put into an aquarium at 9:55 a.m. By the following morning at 8:00, planulae were swimming. Twenty-five hours later the planulae had affixed themselves to the sides of the aquarium. The hydroids reached complete differentiation by July 6, six days after fertilization.

The hydrotheca had 6 obtuse teeth, and was serrated as figured. The hydrocaulus in some cases was distinctly noded beneath the hydranth and again near the hydrorhiza, but remained mostly smooth between these regions: in other cases nodding of the pedicel was total and the nodes numbered as many as 13.

Twenty-four hours later the hydrorhiza was observed to be branching. One day later the tentacles were counted to the number of 12, which seemed to be the average number, although three days later one polyp was noted with 14. By July 12 the colonies had attained their maximum height, two millimeters. Eight days later no change was noted in the growth or differentiation of the polyps. At this time much dirt and algae had gathered upon the hydrothecae, and something seemed to be killing the polyps; so all colonies were killed and preserved.

*Stomatoca atra* Agassiz was observed from July 4 to July 19, 1922.

Ninety medusae of *S. atra* were used for fertilization. Two days later planulae were present. They swam with the blunt end foremost, whirling from left to right for the most part, but occasionally reversing, and when so doing, whirling more slowly. At 72 hours the planulae were 3 times as long as broad; in another day they were 4 times as long as broad and had not affixed themselves to a substratum. They

gradually increased in length until July 10, when they were 6 days old and were approximately 6 times as long as broad. By July 14 few of the planulae were alive. Those which lived were very dark colored, a deep brown-black, and their movement was extremely slow.

In the case of *S. atra* I was unable to get planulae to attach themselves. When they were 10 days old and had elongated so that they were about 6 times as long as wide, a specimen of the marine fish *Hypsagonus quadricornis* Cuvier and Valenciennes was dredged in the inlet and proved to be covered with a *Perigonimus*. The species *P. repens* (Wright) Hincks is the only *Perigonimus* reported from the Puget Sound region by Torrey (1902) or by Fraser (1914). There is however no description of it occurring solely as a commensal. Some snails, *Nassa mendica* Gould, were also found covered with the same *Perigonimus*. Torrey (1902) mentions this same species as substratum for *P. repens*. Calkins (1899) found it on a *Pisa* in Puget Sound. Attachment in all these cases was to a chitinous substratum or one closely allied chemically. Since the hydroid form of *S. atra* has never been reported in the Puget Sound region, and since the planulae would not attach themselves to a glass, stone, shell or crockery substratum, it was conceived that *S. atra* planulae may attach themselves to a chitinous or other chemically allied substratum only. Another specimen of *H. quadricornis* was secured which under the lens appeared to be free from *Perigonimus*. This fish was lightly scraped with a scalpel in order to free it from any *Perigonimus* that one might not be able to see. The fish was then put into the dish with the 10-day-old planulae. They lived together for 5 days, at the end of which time the fish died, probably from the effects of scraping. Examination failed to discover any attached planulae or diminution in the number of planulae in the aquarium, so the result of this experiment was negative. *Stomatoca atra* occurs in such large numbers in Puget Sound that some explanation is necessary to account for the apparent absence of the hydroid, a *Perigonimus*, from which it arises. Dispersal by means of a chitinous substratum in the planula stage, as perhaps by fixation to the exoskeletons of animals, may be the solution to this problem, which is of some moment to the ecologist.

*Aequorea victoria* (Murbach & Shearer), 1903 (Figs. 7-16) was observed from July 11 to August 10, 1922.

Ninety medusae of *A. victoria* were used for fertilization. The rate of early cleavage, all on the same day, was as follows: 2-celled stage at 10:33 a.m., 4-celled stage began at 10:50 a.m., 4-celled stage half-cleft at 10:56 a.m., 8-celled stage completed at 11:28 a.m.,

16-celled stage completed at 12:25 p.m. At nine p.m. larvae were swimming. In some cases the cleavage seemed to be delayed, then suddenly to continue vigorously so that from the 2 or 4-celled stage there would arise the 8 or 16-celled stage almost at once.

The eggs were unusually transparent, with a plainly visible nucleus and granular clear cytoplasm, and were the largest and clearest eggs of the 8 genera tried. The sperms were relatively small. In cleavage the egg membrane wrinkled at the animal pole. Following this the polar body was soon extruded. Cleavage proceeded very rapidly, and in most cases completely divided the egg from the animal pole downward, so that the first two blastomeres remained hanging, united by a slender bridge at the antipolar end, just before cleavage was complete. The second cleavage was vertical but proceeded centrifugally from the two faces of the blastomeres which were in contact. The third cleavage was horizontal but also centrifugal, into a lower tier of 4 larger blastomeres and an upper tier of 4 somewhat smaller cells. Later these two tiers tended to equalization of size.

By afternoon of the second day hundreds of the planulae had attached themselves to the sides of the aquarium, upon glass slides, and upon the threads suspending the slides in the water. In all cases they settled upon the substratum lengthwise and themselves became the hydrorhizae, putting forth a perisarc at once. Within another day the hydrorhiza sent out a single branch near one end, at a right angle to the axis of the planula, showing that the animal had preserved its polarity and was establishing a secondary gradient. This new branch became the hydrocaulus. The perisarc at this time was well differentiated from the coenosarc. A single hydrorhiza only, arose from a single planula.

A day later the hydranth had become differentiated; tentacles began to bud, a mouth was present and a hydrotheca covered the polyp. The top of the hydrotheca was exceedingly tenuous and collapsed above to form a calyptra, which tended to wind spirally about the polyp-body and tentacles, when they were withdrawn. However there were no segments in the hydranth.

Six days after fertilization the hydroid was completely differentiated. It had 12 tentacles, which were webbed for about one-fourth their length proximally. The calyptra seemed to form about 12 creases corresponding to the tentacles. The hydroids arose singly from the unbranched hydrorhizae. Slight annulations appeared near the hydrorhiza on the stem; in some cases there was irregular annulation; in others a twisting spirally of the pedicel. The perisarc was closely

applied to the coenosarc. The diaphragm was strongly developed and the base of the hydrotheca formed a right angle with the stem. During the next three days gonangia were seen developing. No later differentiation took place up to August 10, when the polyps were a month old, and at which time the observations were discontinued due to infection of the colonies.

## DISCUSSION

The general description given in texts of embryology, concerning the attachment of the planulae is that they settle to the *bottom* and affix themselves by the *anterior* end. McBride (1914) says "The planula . . . attaches itself to the bottom by the broad end, which flattens out". Korschelt and Heider (1895) say "The larvae sink to the bottom . . . finally they attach themselves by means of the disc-like enlargement of the anterior end of the body". The latter authors quote Mechnikov's observation on a *Mitrocoma* as an exception rather than the rule. Mechnikov (1886) says "Die larven der erst genannten Gruppe (Oceaniden, Laodice, Mitrocoma) setzen sich . . . , auf den Boden fallen, ihre ursprüngliche Körperform dabei behaltend." T. S. Wright (1863) describes the attachment of *Alcitra* as "the planule . . . spread itself out into a short thread."

The authors of texts seem to base their generalization of this process upon the description of Eudendrium, a gymnoblast. Perhaps the gymnoblastic planulae settle upon the anterior end, while the calyptoblastic planulae which are in general more numerous, affix themselves upon the side. In the case of Stomatopoda, which must arise from a gymnoblastic form, the planulae also arose to the surface, although none were seen to affix themselves.

Mechnikov (1886) figures *Clytia flavidulum* Mechnikov affixing itself by the anterior end. He says "Die Larven setzen sich nicht, mit ihrer ganzen Länger, sondern ausschliesslich mit dem vorderen Ende fest . . . ." This is certainly not the case with *Clytia osteorudi* n. sp. (see page 391). Since nearly all the experiments with *Aequorea* and *Clytia* have been carried on by European investigators the difference in behavior may be due to a difference in either salinity or temperature. The water temperature of the Friday Harbor region taken at the surface by Shelford and Powers (1915) is given as 10.5-11.6° C. The writer recorded 9.6° during the summer of 1917. These temperatures are presumably considerably colder than the Mediterranean and perhaps even British waters.



In the 3 species studied the ova when shed sink to the bottom. After the first division, cleavage always begins from the sides of the blastomeres which are in contact, and proceeds centrifugally. The planulae themselves form the hydrorhizae and exhibit polarity. The hydrocaulus arises at a right angle to the planula, showing a secondary axial gradient. The planulae of the calyptoblasts, *Phialidium gregarium* and *Aequorea victoria* rise to the surface to affix themselves to a substratum; and they settle upon their *sides* to attach.

It would therefore appear that the work of these early investigators should be extended before arriving at generalizations in embryonic development, under conditions obtaining in American waters or in Pacific waters at least.

Wright (1863), in his description of the rearing of the polyp of *Aequorea vitrina* from the egg, designates a "fortnight" as the time required; whereas the whole process in the case of *A. victoria* took place in less than 6 days. At the time Wright worked, the genera *Aequora* and *Zygodactyla* were not clearly differentiated, so that it is not clear whether he used the one or the other.

Fraser (1914) figures *Clytia inconspicua* arising from a planula which is affixed on its side, although he makes no comment upon this; as the figure was from a specimen belonging to Dr. McMurrich, perhaps it did not occur to him that the planula was the hydrorhiza. McBride's (1914) figure after Mechnikov (1886) shows *C. flavidula* attaching apically.

It is probably worth recording that in the case of *C. osterudi* when the living conditions slow down resulting in the destruction of the hydranth from poison or otherwise, it may recover, in which case a new hydrotheca arises from within the old one, a thing which may occur several times, producing a series of hydranths arising from within each other.

Examination of the anal pores in the living medusa of *Aequorea victoria* showed that a continual opening and closing of these pores took place. While open, a continuous stream of material from the circular canal was emitted. Should this system prove to be digestive alone, then this medusa represents the most primitive type of metazoan possessing an anus. This condition suggests the possible development of a single anal pore from a multiple diffuse system.

## DISCUSSION OF NEW SPECIES

From the literature of the Hydroida one is led to the conclusion that the hydroid forms which were reared from the medusae *Phialidium gregarium* and *Aequorea victoria* are undescribed species.

Should this prove to be a fact, the writer proposes the name *Clytia osterudi* for the hydroid stage of the medusa *P. gregarium*, in gratitude to Dr. H. L. Osterud for his kind encouragement in the work. This new species differs from *C. inconspicua* Forbes, which it closely resembles, in its larger size, being 4 times the average height of *C. inconspicua*; in absence of branching of the hydrocaulus; and in possessing usually 6, occasionally 5, rather blunt teeth at the edge of the hydranth. Fraser (1914) makes the character of 7 teeth in the bell specific in the case of *C. inconspicua*. *Clytia inconspicua* was raised from the egg by McMurrich from *Phialidium hemisphericum*. In 1917 Mrs. T. C. Frye, at the Puget Sound Biological Station succeeded in growing a *Clytia* which Bovard and Osterud (1917) contend could not be distinguished from *C. inconspicua* Forbes. This *Clytia* seems to be identical with the author's *C. osterudi*. Mrs. Frye has so far not published the results of her work. In both of these cases the same *P. gregarium*, the most common species at Friday Harbor, was used.

For the hydroid of the medusa *Aequorea victoria* the author proposes the name *Campanulina membranosa* (see page 391), so that future investigators may readily recognize this genus thereby. Fraser (1911 and 1914) who has recently published the most extensive classification of the Pacific forms, fails to mention this membrane as a characteristic of the genus *Campanulina*. This genus was established by van Beneden (1847) who says "Le caractere des tentacules palmés suffit à lui seul pour le distinguer." Greene (1863), Hincks (1868) and Fewkes (1891) so designate it.

In looking over the history of these genera one is struck with inaccuracies of statements and figures. In Claus' (1883) figures 138a and b, and 139, Pl. 17, which are copies of Mechnikov's (1886) work, the tentacles are 15 in number; there is no diaphragm shown; the hydranth extends  $\frac{2}{3}$  the total distance of the polyp. Hincks (1868) however is a very careful worker. His delineation of *Campanulina acuminata* after Wright (1858) shows clearly the great extension of the polyp and the hydranth base making a right angle with the stem.

The description given by Peron and Lesueur (1809) in establishing the species *Aequorea forskalea* is very meager and is based upon specimens from the Mediterranean. I am unable to align their

description with the *Aequorea* of Friday Harbor, although Fraser (1911 and 1914) lists it as such. But Peron and Lesueur (1809) expressly state "Ombrelle discoïde; très-déprimé, presque plane", a description which is clearly not the *Aequorea* of the Friday Harbor region. Torrey's (1909) description of *A. coerulescens*, save for the distinctive blue color, seems very close to the form from Friday Harbor. However the *A. coerulescens* photographed by Bigelow (1909), is certainly not the same, as the formation of the tentacles is different. The figure 16 drawn from a living medium sized specimen will best explain itself. As above indicated one of the outstanding features of this species is the great thickness of the mesoglea, which forms an almost spherical globe of jelly projecting into the gastric cavity. No reference was found to this character in any of the descriptions except Torrey's *A. coerulescens* Brandt (1835). In the hundreds of specimens which the writer has examined, the mouth has nearly always been open, with the mesoglea projecting into it, although occasionally the mouth has been closed. Since *A. forskalea* was originally described from the Mediterranean, an inland sea, it is not highly probable that the same species would find its dispersal as far away and in the direction of the Pacific Ocean on the American side. If such were its dispersal, then the *Campanulina* from which it arises must be very common. But this appears not to be the case, for as hydroids go, *Campanulinae* are rare.

*Aequorea cyanea* de Blainville (1834, Fig.) is the closest delineation of the Friday Harbor species which the author has seen, but this had the characteristic blue color which the Friday Harbor one lacks. This color may well be due to environmental conditions however. *A. violacea* Milne-Edwards (1841) is altogether too flat and corresponds to the original description of Peron and Lesueur (1809). Mayer (1910) reports only *A. victoria* Maas from the Puget Sound region. He thinks that this may be identical with *A. forskalea*, but he does not report *A. forskalea* as occurring in Puget Sound. Fraser (1911) thinks *A. vitrina* Gosse is identical with *A. forskalea*, and considers that a *Campanulina* he obtained from the Puget Sound region is the same species as that reared by Wright (1863) from *A. vitrina*.

When this work was begun it was the aim to study the life cycle and embryology of certain medusae, among which was the large *Aequorea* at Friday Harbor, commonly referred to *A. forskalea* (Bovard & Osterud 1917). Murbach and Shearer give a description which is close enough to the *Aequorea* of Friday Harbor to amount to identity, under the name of *Mesonema victoria* (1903). Since the medusa in

question is a true *Aequorea* then the species should be *Aequorea victoria*. It is certainly not identical with *A. forskalea*. A description of the Friday Harbor *Aequorea* is included in this paper.

#### DESCRIPTION OF NEW SPECIES

##### *Clytia osterudi* n. sp.

Trophosome: colony 2 mm, from a branching hydrorhiza: stem unbranched; pedicel slender and 3 times as long as the hydranth, annulated throughout or spirally twisted throughout, or in most cases with a portion in the center smooth; hydrotheca campanulate; teeth in the bell 6 or 5, rather blunt; diaphragm strong; tentacles 12 (11-14).

Gonangium: solitary, campanulate; gonostyle obovate; pedicel annulated.

Distribution: laboratory specimens only. San Juan Island in Puget Sound.

Medusa: *Phialidium gregarium* Haeckel; bell nearly hemispherical, 18 mm wide, 12 mm high; tentacles 56, with large ellipsoid to spherical bulbs; 1, 2 or 3 concretions between each pair of tentacles; radial canals 4, with gonads 3 mm long on the distal third of the canal, faintly colored whitish, bluish, grayish or pinkish. The specimen described is a male of average size.

##### *Campanulina membranosa* n. sp.

Trophosome: colony minute,  $\frac{1}{2}$  to 1 mm, hydrorhiza unbranched; stem unbranched and very short, about half the length of the hydranth and rather thick, annulated or wrinkled throughout; hydrotheca cylindrical, making a right angle at the base with the pedicel, and fitting very tightly to the polyp, becoming very tenuous above and terminating in a series of creases which wind spirally above the tentacles, forming the calyptra; hydranth tentacles 12, disposed in two alternate rows, united by a web proximally for about  $\frac{1}{4}$  to  $\frac{1}{3}$  their length, the web studded with large nematocysts mostly near the tentacles; polyp exceedingly extensile, at least  $2\frac{1}{2}$  times the length of the hydrotheca.

Gonangium: solitary, arising from a simple hydrorhiza and globular when very young, becoming obovate on maturity.

Distribution: laboratory specimens only. San Juan Island in Puget Sound.

Medusa: *Aequorea victoria* n. sp.; bell a transparent faint slate-bluish color, 3 times as wide as high, the center consisting of a nearly perfect sphere of jelly which projects into the gastric cavity; stomach relatively small, with many lappets bordering the mouth; ra-

dial canals twice as many as mature tentacles; tentacle bulbs colored a deep brown; tentacle buds of the second order as many as the tentacles; tentacle buds of the third order twice as many as tentacles, between each tentacle and tentacle bud of the second order; lithocysts with 1, 2 or 3 concretions, 1 or 2 between each pair of tentacle buds or between a tentacle and a tentacle-bud; "excretory pores," which are probably parts of a multiple anal system, all around the inside of the bell on the circular canal, one anus at the basis of each radial canal; gonads on the distal  $\frac{3}{4}$  of each radial canal, usually opalescent but sometimes greenish, bluish, grayish or pinkish in color; lappets of mouth  $\frac{3}{4}$  as many as mature tentacles. In one specimen typical except for its small size the bell was 38 mm wide and 12 mm high; radial canals 61; tentacles 32; lappets 24. This species reaches a diameter of 10 to 12 cm.

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## PLATE 37

*Phialidium gragarium* Haeckel.

Drawings with camera lucida except as indicated.

Fig. 1. Aboral view; specimen 18 mm in diameter, 12 mm high, showing velum, gonads and manubrium.  $\times 1.33$ .

Fig. 2. Side view.  $\times 1.33$ .

Fig. 3. Young gonangium.  $\times 46.67$ .

Fig. 4. Adult hydranth.  $\times 106.67$ .

Fig. 5. Edge of bell of hydrotheca showing 5 or 6 teeth.  $\times 183.33$ .

Fig. 6. Position of diaphragm.  $\times 183.33$ .

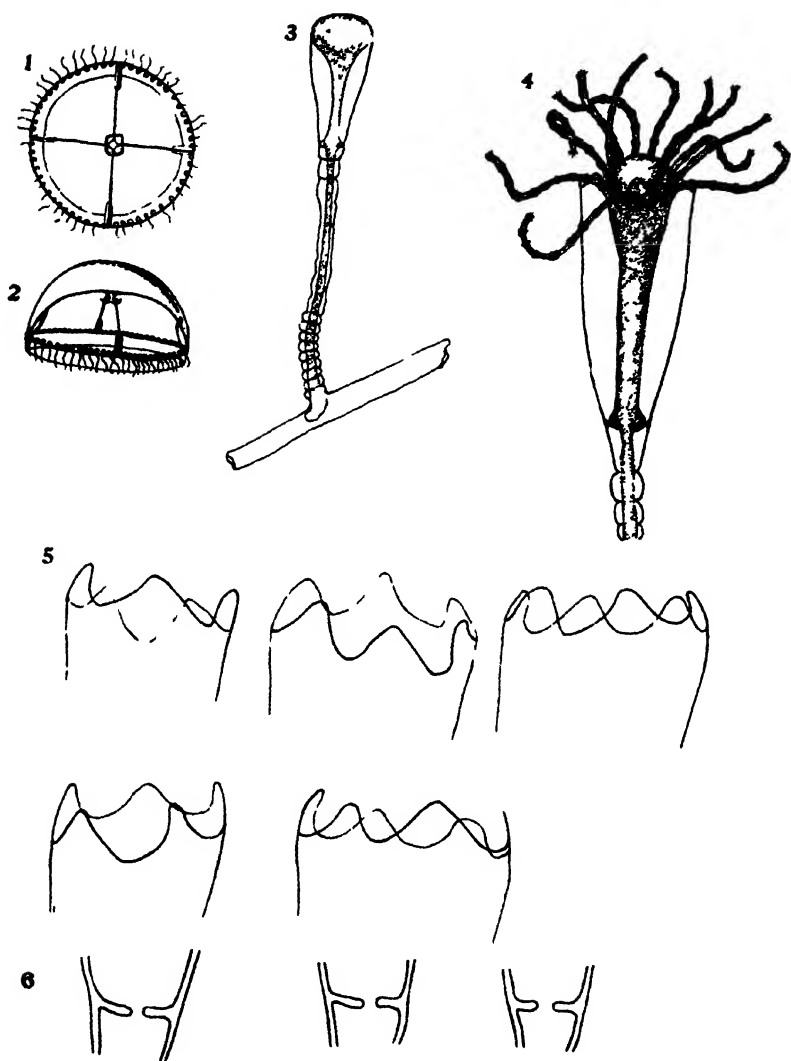


PLATE 37



## PLATE 38

*Aequorea victoria.*

Drawings with camera lucida except as indicated.

Fig. 7. Group of planulae 72 hours old attached laterally to substratum; some have put out a branch, the future polyp.  $\times 135.33$ .

Fig. 8. Group of young colonies 96 hours old showing further differentiation into pedicel, hydranth, tentacle buds, hydrotheca and calyptra.  $\times 135.33$ .

Fig. 9. Sketch of gonangium 6 days old. Approximately  $\times 133$ .

Fig. 10. Sketch of hydranth 6 days old showing folds of calyptra. Approximately  $\times 133$ .

Fig. 11. Sketch of hydranth 6 days old, expanded. Approximately  $\times 133$ .

Fig. 12. Sketch of stage of gonangium less developed than fig. 9 above, 6 days old. Approximately  $\times 133$ .

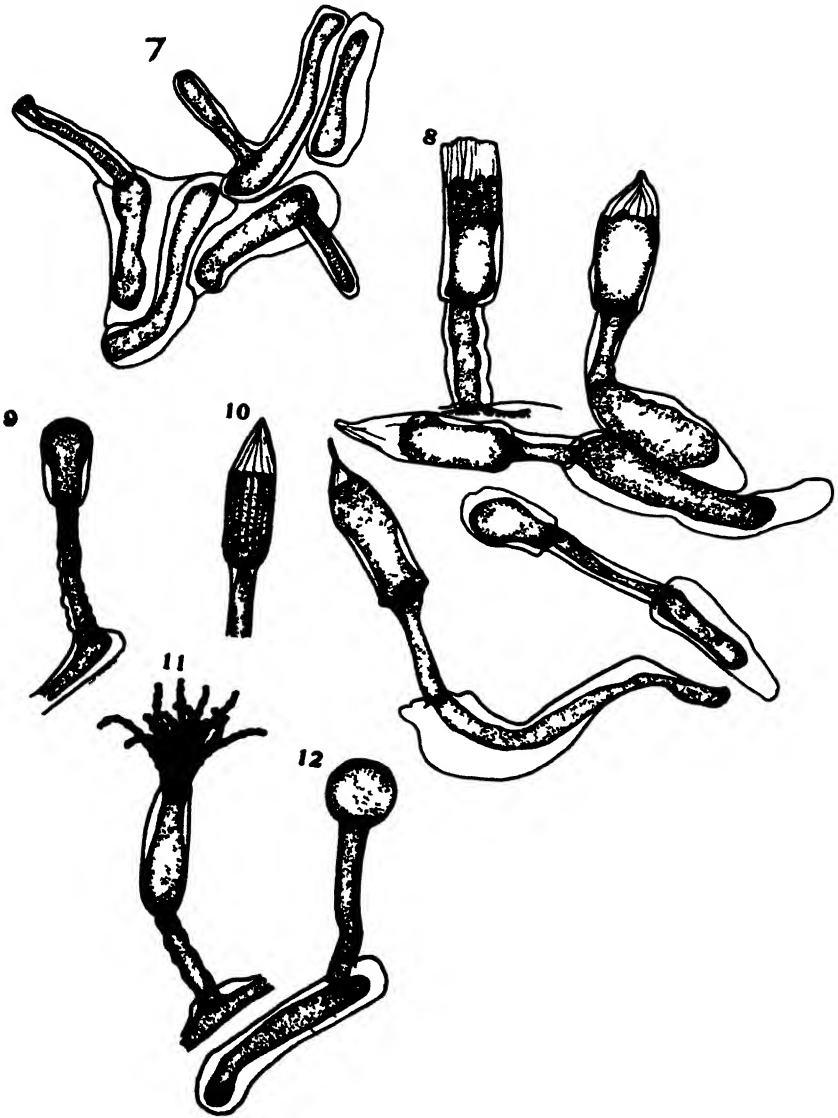


PLATE 38

## PLATE 39

*Aequorea victoria.*

Drawings with camera lucida except as indicated.

Fig. 13. Adult polyp showing webbed tentacles in an upper and lower series, extreme distensibility of polyp and short stolon.  $\times 106.67$ .

Fig. 14. Oral view showing thread cells on web.  $\times 106.66$ .

Fig. 15. Gonangium 9 days old.  $\times 106.67$ .

Fig. 16. Medusa, drawn from a living specimen; diameter of bell 38 mm, height 12 mm, tentacles 33, velum and tentacles on side away from observer not drawn.  $\times 1.33$ .

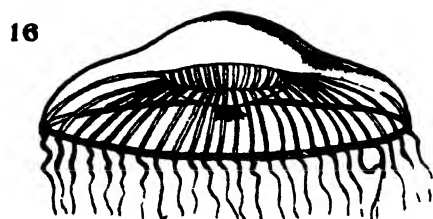
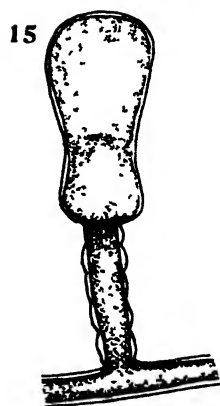
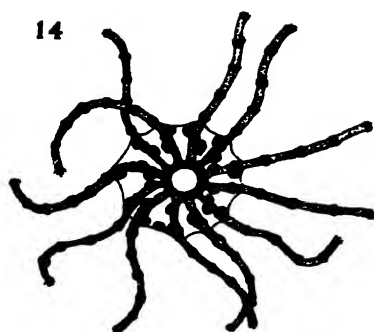
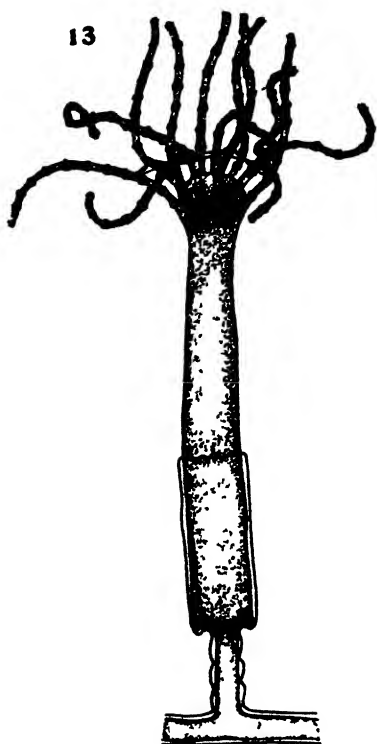


PLATE 39



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## CORRECTIONS

- Page 4, line 11 for "*Culpea*" read "*Clupea*".
- Page 5, 4th line from bottom; for "*Myoxocephalus*" read "*Myxocephalus*".
- Page 12, line 18; after "Van Slyke" add "and Cullen".
- Page 35, line 4; drop "m" from "*beringianam*".
- Page 46, 3rd line from bottom; for "bare" read "base".
- Page 70, 8th line from bottom; for "Rays unbranched in ours" read "Rays branched in twos".
- Page 71, 9th line from bottom; for "slended" read "slender".
- Page 79, line 7; for "statment" read "statement".
- Page 79, line 21; for "1862" read "1682".
- Page 82, line 21, Fucoxanthin; for " $C_{40} H_{56} O_6$ " read " $C_{40} H_{54} O_6$ ".
- Page 90, line 17; for "1882" read "1682".
- Page 97, line 1; for "1-9" read "1-11", and for "10" read "12".
- Page 97, line 3; for "50 2.5-3.0" read "100 2.5-3.0".
- Page 103, graph 12; the abscissal upright should have a mark 13.5 mm above the base, that division to represent 5 animals (basis 100).
- Page 123, line b.; for "sea water a" read "sea water at".
- Page 125, 6th line from the bottom; move "Pulsating normally" down one line, making that line read "155 4°C 4°C Pulsating normally".
- Page 141, line 5; for "*Illinois*" read "*Idaho*".
- Page 156, 2nd column of table; add a second degree sign to each of the numbers 5.4° and 2.5° to correspond with the 4th footnote.
- Page 157, table 7, 1st column, lines 14 and 15; for "537.0,P" read "537.0,A", and for "539.0,A" read "539.0,P".
- Page 160, table 10, head of 6th column; for "m.c. light units" read "100 m.c. light units".
- Page 162, line 13; for "he" read "the".
- Page 164, lines 6 and 7; for "for each 5 meters of group of 5 meters" read "by 5-meter intervals".
- Page 189, line 4; for "1" read "31" and for "2" read "32".

- Page 189, line 13; for "1 and 2" read "31 and 32".
- Page 189, 12th line from bottom; for "2" read "32".
- Page 190, upper part of plate; "*clear sky-water choppy*" should apply only to line of graph ending farthest to left above.
- Page 191, line 2; for "2" read "32".
- Page 193, 4th line from bottom; for "1" read "31".
- Page 272, 4th line from bottom; for "(?)" read "1909".
- Page 272, 2nd line from bottom for "(?)" read "1908".
- Page 313, 11th line from bottom; for "those" read "the cells".
- Page 315, line 5; for "10" read "16".
- Page 315, line 8; for "formation" read "fuction".
- Page 316, line 7; for "96" read "98".
- Page 319, line 9; for "1" read "(1)".
- Page 324, 9th line from bottom; for "he" read "the".
- Page 328, line 3, Fig. 12....; for "a" read "a".
- Page 328, line 10; for the line "Fig. 12. A callus.....sieve cell." read "Fig. 15. A mass of material (a) in a sieve tube (b) with stringy portions".
- Page 331, line 21; for "*vesiculosis*" read "*vesiculosus*".





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**MARINE SHELLS  
OF  
PUGET SOUND AND VICINITY**

**By  
IDA SHEPARD OLDROYD**



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## ANNOUNCEMENT

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## Marine Shells of Puget Sound and Vicinity

IDA SHEPARD OLDROYD  
Stanford University, California

### INTRODUCTION

This report is the result of four years of collecting, dredging and study of the marine, shelled mollusca and brachiopoda of Puget Sound, Vancouver Island and the Queen Charlotte Islands. It was at first the intention to report on the Puget Sound fauna alone, but the species overlap in such a way that it was thought best to include those of the northward islands mentioned. It has been the endeavor to make the list as complete as possible within the area extending from the northern end of the Queen Charlotte Islands southward to the Strait of Juan de Fuca, and within the Sound to Olympia. I have called this area the Puget Sound subprovince of the Oregonian province. A few species are included which have not so far been found within the region covered but are known from near by. During June and July 1917 to 1920, Mr. T. S. Oldroyd and I spent several weeks at the Puget Sound Biological Station at Friday Harbor, Washington, and at the Dominion Station at Nanaimo on Vancouver Island. At both stations we were afforded every facility possible by their respective directors, Dr. T. C. Frye and Dr. C. McLean Fraser. This report includes about 520 species of mollusca and 8 species and varieties of brachiopoda. Those marked with an asterisk (\*) were collected by Mr. Oldroyd and myself, or by others under our direct observation.

The species *Thyasira bisecta*, *Purpura foliata*, *Pecten hericius*, *P. hindsii*, *P. kincaidi*, *P. islandicus pugetensis*, *P. caurinus*, *Chrysodomus tabulatus*, *Thais lamellosa*, *T. canaliculata* and many of the chitons are at their best in the region covered. The genera *Chrysodomus*, *Buccinum*, *Colus*, *Astarte*, *Serripes*, *Thracia*, *Thyasira*, *Pandora*, *Macoma*, *Leda* and *Yoldia* range from the Arctic regions to Puget Sound as shore forms or in deeper water, but as they range southward they are more deeply submerged. *Purpura foliata*, *Thais canaliculata* and *Tritonalia interfossa* are shore forms here, and are fine specimens. *Phacoides annulatus* is specially fine here in shallow water. *Thracia trapezoides* was described from a fossil from Astoria, Oregon; we dredged it living off San Juan and Lopez Islands, also at the sponge beds near Nanaimo, Vancouver Island. This is the first time it has been reported alive. *Thyasira bisecta* was dredged in about 3 fathoms off Brown Island, where three living and many

dead specimens were obtained. The records show that it has been dredged along the southeastern shore of the Alaska Peninsula, in 69 fathoms, mud bottom, at a temperature of 6.5° C. It was reported to be 50 mm long; the largest we found was 80 mm. Another specimen from 135 fathoms, in Puget Sound, measured 74 mm in extreme length and about 28 mm in diameter. This species was described from a fossil from Astoria, Oregon, and is given as 25 mm long. It is found in the Pliocene at San Pedro, California. The delicate shell *Philobrya setosa* Carpenter, has been dredged near the Dominion Station. It is like a minute Pinna without the sharply pointed beaks. The animal is viviparous. The shell structure is similar to that of Pinna, in two layers, the outer fibrous, the inner nacreous. It is fastened by a very slender byssus. Many of the species found living in this region today are found fossil in the lower Pleistocene series at San Pedro, California, and elsewhere on the Pacific coast, suggesting that the climate at the time these beds were formed was the same as in the Sound today.

The following list of species found within certain areas are given for comparison.

#### FOUND IN PUGET SOUND

<i>Alvania filosa</i> Carpenter	<i>Odostomia avellana</i> Carpenter
<i>Alvania sanjuanensis</i> Bartsch	<i>Odostomia engbergi</i> Bartsch
<i>Barleeia sanjuanensis</i> Bartsch	<i>Odostomia gouldi</i> Carpenter
<i>Bittium attenuatum boreale</i> Bartsch	<i>Odostomia grippiana</i> Bartsch
<i>Bittium sanjuanensis</i> Bartsch	<i>Odostomia inflata</i> Dall & Bartsch
<i>Callistochiton aepynotus</i> Dall	<i>Odostomia nuciformis</i> Carpenter
<i>Cerithiopsis paramoea</i> Bartsch	<i>Odostomia sanjuanensis</i> Bartsch
<i>Colus georgianus</i> Dall	<i>Odostomia satura</i> Carpenter
<i>Colus morditus</i> Dall	<i>Odostomia tacomaensis</i> Dall & Bartsch
<i>Cyclostremella concordia</i> Bartsch	<i>Odostomia washingtonia</i> Bartsch
<i>Ischnochiton retiporosus punctatus</i>	<i>Pecten islandicus pugetensis</i> I. Oldroyd
Whiteaves	<i>Pecten kincaidi</i> I. Oldroyd
<i>Iselcia obtusa laxa</i> Dall	<i>Pseudomurex kincaidi</i> Dall
<i>Lacuna porrecta exaequata</i> Carpenter	<i>Pseudopythina myaciformis</i> Dall
<i>Leda cellulida</i> Dall	<i>Pseudopythina rugifera</i> Carpenter
<i>Margarites funiculata</i> Carpenter	<i>Thracia trapezoides</i> Conrad
<i>Margarites inflatula</i> Dall	<i>Triforis carpenteri</i> Bartsch
<i>Margarites lirulata conica</i> Carpenter	<i>Tritonalia fraseri</i> I. Oldroyd
<i>Margarites lirulata obsoleta</i> Carpenter	<i>Turbonilla aurantia</i> Carpenter
<i>Margarites lirulata subelevata</i> Carpenter	<i>Turbonilla pugetensis</i> Bartsch
<i>Margarites tenuisculpta</i> Carpenter	<i>Turbonilla victoriana</i> Dall & Bartsch
<i>Melanella comoxensis</i> Bartsch	<i>Vencricardia stearnsii</i> Dall
<i>Melanella macra</i> Bartsch	<i>Vitrinella columbiana</i> Bartsch
<i>Melanella tacomaensis</i> Bartsch	

FOUND ABOUT THE QUEEN CHARLOTTE ISLANDS AND ON THE WEST  
SIDE OF VANCOUVER ISLAND

<i>Bittium attenuatum boreale</i> Bartsch	<i>Odostomia spreadboroughi</i> Dall & Bartsch
<i>Cadulus aberrans</i> Whiteaves	<i>Odostomia vancouverensis</i> Dall & Bartsch
<i>Cidarina carlotta</i> Dall	<i>Odostomia youngi</i> Dall & Bartsch
<i>Cytharella victoriana</i> Dall	<i>Tegula pulligo taylori</i> n. var.
<i>Liocyma scammoni</i> Dall	<i>Turbonilla barkleyensis</i> Bartsch
<i>Lora maurellei</i> Dall & Bartsch	<i>Turbonilla lyalli</i> Dall & Bartsch
<i>Mangelia carlottae</i> Dall	<i>Turbonilla macouni</i> Dall & Bartsch
<i>Micranellum barkleyense</i> Bartsch	<i>Turbonilla newcombei</i> Dall & Bartsch
<i>Odostomia barkleyensis</i> Dall & Bartsch	<i>Turbonilla pesa</i> Dall & Bartsch
<i>Odostomia cassandra</i> Bartsch	<i>Turbonilla rinella</i> Dall & Bartsch
<i>Odostomia columbiana</i> Dall & Bartsch	<i>Turbonilla talma</i> Dall & Bartsch
<i>Odostomia cypria</i> Dall & Bartsch	<i>Turbonilla taylori</i> Dall & Bartsch
<i>Odostomia hypatia</i> Dall & Bartsch	<i>Turbonilla valdezi</i> Dall
<i>Odostomia pharcida</i> Dall & Bartsch	<i>Yoldia vancouverensis</i> Smith
<i>Odostomia quadrae</i> Dall & Bartsch	

CIRCUMBOREAL

<i>Admete couthouyi</i> Jay	<i>Modiolus modiolus</i> Linne
<i>Astarte fabula</i> Reeve	<i>Mya truncata</i> Linne
<i>Buccinum glaciale</i> Linne	<i>Mytilus edulis</i> Linne
<i>Cylichnella alba</i> Brown	<i>Nucula tenuis</i> Montagu
<i>Kellia suborbicularis</i> Montagu	<i>Pandora glacialis</i> Leach
<i>Lasaea rubra</i> Montagu	<i>Pecten islandicus</i> Mueller
<i>Leda minuta</i> Fabricius	<i>Saxicava arctica</i> Linne
<i>Lima subauriculata</i> Montagu	<i>Saxicava pholadis</i> Linne
<i>Lora harpularia</i> Couthouy	<i>Serripes gronlandicus</i> Gmelin
<i>Lora rosea</i> M. Sars	<i>Tachyrhynchus reticulatus</i> Mighels
<i>Lora turricula</i> Montagu	<i>Thyasira gouldi</i> Philippi
<i>Lyonsia striata</i> Montagu	<i>Trichotropis borealis</i> Broderip & Sowerby
<i>Macoma balthica</i> Linne	<i>Turtonia minuta</i> Fabricius
<i>Macoma calcarca</i> Gmelin	<i>Yoldia limatula</i> Say
<i>Margarites helcinus</i> Phipps	<i>Yoldia thraciiformis</i> Storer
<i>Modiolaria corrugata</i> Stimpson	
<i>Modiolaria nigra</i> Gray	

FOUND IN JAPAN

<i>Rotula californiensis</i> Philippi	<i>Pecten alaskensis</i> Dall
<i>Cardium ciliatum</i> Fabricius	<i>Pododesmus macroschisma</i> Deshayes
<i>Cardium corbis</i> Martyn	<i>Psammobia californica</i> Conrad
<i>Chrysodomus liratus</i> Martyn	<i>Serripes gronlandicus</i> Gmelin
<i>Cryptochiton stelleri</i> Middendorff	<i>Solariella perambilis</i> Carpenter
<i>Macoma calcarca</i> Gmelin	<i>Spisula alaskana</i> Dall
<i>Macoma incongrua</i> Martens	<i>Thais lamellosa</i> Gmelin
<i>Macoma secta</i> Conrad	<i>Thais lima</i> Martyn
<i>Natica aleutica</i> Dall	<i>Trophon beringi</i> Dall
<i>Paphia staminea</i> Conrad	<i>Trophon multicostratus</i> Eschscholtz

olive color, moderately convex, with conspicuous beaks; in perfect specimens the prodissoconch is rather large, smooth and white, but is commonly eroded; the nepionic shell outside the limits of the prodissoconch is distinguished from the rest by having only delicate concentric sculpture, which abruptly changes to a stronger sculpture of somewhat irregularly concentric ridges with narrower interspaces crossed by numerous fine uniform radial striae; there is no well defined lunule or escutcheon; the margin in front of the beaks is marked by a radial impressed space, the margin inclosed by which is a little pouting; the interior of the shell is pearly, radially striate near the finely crenulate margin; the chondrophore is narrow and projects backward obliquely into the cavity of the valves; there are about 8 anterior and 12 posterior teeth. Length, 6; height, 5.2; diameter, 3.5 mm. (Dall). Queen Charlotte Islands, in 876 fathoms.—Queen Charlotte Islands to Anacapa Island, California.

*Nucula* (*Acila*) *castrensis* Hinds, 1884. (Plate 1, fig. 11). Shell small, trigonal, convex, of medium thickness; umbones posterior to center, turned posteriorly; anterior end longer than posterior, rounded; posterior end short, truncated; surface divaricately sculptured; hinge with prominent internal cartilage-pit and numerous sharp teeth on each side. Length, 11.5; height, 10; diameter, 8 mm. (Arnold). Off Orcas Island, Washington, in 25-35 fathoms.—Bering Sea to San Diego, Calif.

### Family LEDIDAE

LEDA Schumacher, 1817

Shell oblong, rounded in front, produced and pointed behind; margins even; pallial line with a small sinus; umbonal area with a linear impression joining the anterior adductor. (Tryon S. S. Conch.) Type *Leda pernula* Mueller.

*Leda cellulita* Dall, 1896. (Plate 1, fig. 7). Shell solid, with a dull olive-gray epidermis, moderately convex, with subcentral, not prominent beaks, base profoundly arcuate, anterior dorsal slope rounded, posterior straight or slightly concave; posterior extreme bluntly pointed; escutcheon large, transversely striate; lunule not differentiated but similarly striated; sculpture of fine sharp concentric grooves with interspaces, less arcuate than the incremental lines; chondropore small, triangular, not projecting, with 22 anterior and 16 posterior hinge teeth on the cardinal border. Length 15.5; height,

10; diameter, 7.2 mm. (Dall). Off San Juan Island, Wash., in 25-30 fathoms.\*—Puget Sound.

*Leda minuta* Fabricius, 1776. (Plate 1, fig. 5). Shell oblong, pyriform, tumid, beaks at anterior third, slightly elevated, obtuse, inclined inwards, anterior dorsal margin sloping so as to bring the somewhat acutely rounded point about midway to the base; posterior dorsal margin with about the same slope as the front, direct and slightly upturned very near the tip, which is very small and squarely truncate; ventral margin full and well-rounded, with a very slight emargination under the tip; dorsal face very broad, with a wide, flattened or somewhat depressed space, destitute of riblets, in front of the beaks, and a long lanceolate one defined by a sharp ridge behind; disks of the valves very tumid, with a shallow sub-marginal channel behind; surface deeply grooved concentrically so as to form conspicuous reflexed riblets, which terminate on reaching the dorsal areas; epidermis dusky chestnut. Interior slightly nacreous, showing the external riblets, with a very distinct tip; hinge with very small oblique ligament pit, with about 12 teeth before and 14 behind it. (Gould Invert. Mass.) Length 11; height 6; diameter 3 mm. Off San Juan Island, Wash., and common in all the dredging stations, 15-20 fathoms.\*—Arctic Ocean to San Diego, Calif.

This species has a number of varieties, from the short, fat, to the form that comes close to *L. hamata* in shape. We dredged some 4 or 5 forms of it at the various stations in Puget Sound.

*Leda acuta* Conrad, 1831. (Pl. 6, fig. 1, Conrad's Amer. Marine Conch.) Shell ovate, elongated, convex, with numerous, regular, concentric striae; posterior side slightly recurved, and very acute at the extremity; epidermis dark green. (Tryon Amer. Marine Conch.) Length 6; height 4 mm. Departure Bay, Vancouver Island, by Rev. G. W. Taylor.\*—Nazan Bay, Atka Island, Alaska, to Gulf of California.

*Leda hamata* Carpenter, 1864. (Plate 25, fig. 4). Shell small, elongate-trigonal, convex, thin, umbones anterior, turning slightly toward the posterior end, rounded anteriorly, much lengthened, narrowed and abruptly truncated posteriorly; surface sculptured by strong, concentric raised lines; a raised band, strongly transversely sculptured by continuations of the concentric ridges, passes from the umbo, around the escutcheon, to the elongated, raised process; escutcheon deep-set, smooth. Length, 8; height, 5; diameter, 2.5 mm.



(Arnold). Off San Juan Island, Wash., in 25-35 fathoms.\*—Puget Sound to Panama.

*Leda penderi* Dall, 1910. (Plate 12, figs. 3, 4). Shell small, solid, equivalve, nearly equilateral; the posterior side slightly longer, lighter or darker olivaceous in color, tumid, with the anterior end rounded; the posterior angularly rostrate, the extreme end slightly recurved; anterior and posterior slopes nearly equal, the former a little convex, the latter slightly concave, the base convexly arcuate; lunule not defined, represented by a lanceolate narrow space, longitudinally striated; escutcheon similarly striated, impressed, broadly lanceolate, bounded in each valve externally by a stout keel, the apposed margins hardly pouting in the median line; beaks low and adjacent; sculpture of the disk composed of numerous concentric ridges, less arcuate than the incremental lines, and separated by wider interspaces; more adjacent near the anterior end of the shells. An obscure radial ridge extends from the beaks toward the anterior end of the base. Interior polished, bluish, with entire margin. Ligament small, wholly internal. Hinge-teeth small, V-shaped, numbering 16 anterior (of which 6 are small and crowded), and 14 posterior (of which 6 are very small), separated by the ligamentary pit, which is small and not projecting. Length of average adult, 9.2; beaks behind the anterior margin, 4.2; maximum height, 6; maximum diameter, 5 mm. (Dall & Bartsch). Departure Bay, Vancouver Island.\*—Queen Charlotte Islands to Santa Barbara, Calif.

The nearest recent species to this is *Leda excavata* Hinds, from Panama Bay, which is somewhat smaller, with a sharper posterior angle and more recurved rostrum, fewer posterior and more anterior teeth, and more deeply excavated escutcheon. With the present species was associated the widespread *L. acuta* Conrad, which is a more elongated and less inflated species. (Dall & Bartsch).

*Leda fossa* Baird, 1863. (Plate 1, fig. 6; plate 45, fig. 7). Shell small, elongated, convex, thin; umbones anterior, turning slightly toward the posterior end, which is elongated, narrow and truncated; posterior end short and evenly rounded; sculpture nearly obsolete, a few concentric lines discernible; escutcheon long, narrow, smooth, deep-set; an elongated process on the middle of posterior end; hinge with small internal cartilage-pit, numerous teeth on each side. (Arnold). Length 11, height 6, diameter 3.8 mm. Off Matia Island, Wash., in 35 fathoms.\*—Kotzebue Sound, Alaska, to Puget Sound.

*Leda leonina* Dall, 1896. (Plate 44, fig. 12). Shell rather thin,

compressed, with the low beaks at the anterior third; base slightly arcuate, anterior and rounded, posterior dorsal slope concave, lunule and escutcheon narrow, elongate, strongly impressed, smooth, with the valve margins elongated; rostrum broadly and a little obliquely truncate; sculpture of thin sharp concentric lamellae strongest on the rostrum; epidermis dull olive-gray, dehiscent; hinge with 22 anterior and 28 posterior teeth, the chondropore small, inconspicuous. Length, 23.6; height, 11; diameter, 5.25 mm. (Dall). Strait of Fuca to latitude 36° north.

YOLDIA Moeller, 1842

Shell oblong, slightly attenuated behind, compressed, gaping, smooth or obliquely sculptured, with a dark olive shining epidermis; external ligament slight; cartilage as in *Leda*; pallial sinus deep. (Woodward, Manual Conch.)

*Yoldia thraciaeformis* Storer, 1838. (Plate 1, fig. 1). Shell ovate, transverse, equivalve, inflated, gaping at both extremities, with numerous very distinct, concentric lines of increment, covered with a yellowish-green, polished epidermis in young specimens, concealed under a black pigment, which readily rubs off in the recent specimens, giving a sooty appearance to the fingers. In the adult shell the epidermis is rather a dirty brown. Beaks slightly prominent over the hinge margin. An obtuse angle, more elevated and wider at its lower half, runs obliquely from the umbones to the posterior base of the shell, serving as a boundary to the anterior inflated portion. Posterior portion of shell much compressed, its epidermis is of a lighter color, and the striae of increase are much more apparent than upon the anterior portion. Anterior margin rounded; posterior somewhat truncated, within perlaceous. Teeth numerous and peculiar; those contiguous to hinge small; those farther removed from fosset very strong, sharp, angulated, higher than wide; the teeth of one valve shutting very closely into the excavated teeth of the opposite valve, form a very powerful hinge. Fosset capacious. (Storer). Length 50, height 30, diameter 15 mm. Off Matia Island, Washington, in 35 fathoms; off the entrance to East Sound and in Deer Harbor, Wash., in 25 fathoms.\*—Arctic Ocean to Puget Sound; Atlantic.

"This shell, of which I have seen but one perfect specimen, and which, in its general outline, resembles somewhat a *Thracia*, I took from the stomach of a *Platessa*—the *dentata* of Mitchill—called by our fishermen, Sand dab: this fish was caught off Provincetown, Cape

Code, in about 30 fathoms, and brought to our market the last of Dec. 1873." (Storer).

*Yoldia beringiana* Dall, 1916. (Plate 1, fig. 4). Shell large, thin, smooth, except for lines of growth, brilliantly polished, inequilateral, hardly rostrate, rounded at each end, less compressed behind than *Y. secunda*; color a rich yellowish brown; escutcheon striated, narrower than in *secunda*; beaks very low, 24 anterior and 17 posterior teeth, the resilifer ample, cup-shaped, projecting; the pallial sinus is rather large and rounded. Length, 40; height, 22; diameter, 16 mm. (Dall). Off Seattle, Wash.; north of Five Fingers Island, B. C., in 200 fathoms.\*—Bering Sea to Anacapa Island, Calif.

*Yoldia vancouverensis* E. A. Smith, 1880. Shell almost equilateral, transversely elongate-oval, acuminate posteriorly, slightly gaping at both ends, clothed with a greenish olivaceous epidermis which is darker toward the ventral margin and varied at intervals with dark zones. Surface not very glossy, marked with concentric lines of growth and close microscopic striation and granulation. Anterior side a trifle the longer, regularly rounded at the margin, posterior more arcuate. Area distinct. Length, 12; height, 22.5; diameter, 6 mm. (E. A. Smith).—Known only from Vancouver Island.

*Yoldia martyria* Dall, 1907. (Pl. 9, fig. 16, Bull. Nat. Hist. Soc. Brit. Columbia, No. 2). Shell olive-greenish, polished, smooth, nearly equilateral; surface sculptured only by obsolete incremental lines; two or three rays extend obliquely backward from the beaks, due to some variation of color in the periostracum, but these do not interrupt the smoothness of the surface; beaks full but not prominent; base arcuate, posterior end roundly pointed, subrostrate, compressed, slightly recurved; there is a long narrow, slightly impressed lunule and escutcheon, both of which are delicately striate longitudinally, and the dorsal margins included within them are not quite closed; the rostrum gapes slightly, but there is no obvious pedal gape; within the shell is white, with a deep rounded pallial sinus; chondrophore rounded, one-half of it projecting below the hingeplate; there are 21 anterior and 17 posterior teeth, narrow, high, and rather strong. Length of shell, 26; height, 15; diameter, 11 mm. (Dall). Departure Bay, Vancouver Island, in 10-20 fathoms, by Dr. C. M. Fraser.\*—Kasaan, Alaska, to Gulf of California.

This species is closely related to *L. montereyensis*, from which it differs especially in its more compressed and acute posterior end. (Dall).

*Yoldia montereyensis* Dall, 1893. (Pl. 2, fig. 18, Bull. Nat. Hist. Soc. Brit. Columbia, No. 2). Shell large, stout, inflated, with a polished dark greenish olive epidermis; beaks eroded in all the specimens, situated in the anterior part of the middle third of the shell, not prominent; valves full and rounded, anterior end evenly rounded, into the upper and basal margins; posterior end narrower, rounded, the extreme end nearer the cardinal margin with which it almost forms an angle, below sloping obliquely toward the basal margin, with a very obscure broad ray impressed in a radiating manner from the beaks toward the oblique slope, the profile of which it does not perceptibly indent; surface sculptured with one or two darker concentric color zones and a microscopic, irregular, radially disposed wrinkling, most conspicuous at the margins of the impressed ray; posterior cardinal margin nearly straight, anterior ditto, evenly rounded; interior porcellaneous white, the pallial sinus not reaching the middle vertical line of the shell, broad and rather rounded; ligamental fosset large, cup-like; anterior teeth V-shaped, about 22 in number, strong and prominent; posterior teeth similar, and forming an equally long line not only 18 in number, the posterior cardinal margin showing a long narrow impressed area very feebly marked. Length of shell, 32; beak from anterior end, 12; vertical from beak to base, 17; maximum diameter, 13 mm. (Dall). Puget Sound, and off Vancouver Island.—Chirikoff Island, Alaska, to San Diego, Calif.

This fine shell recalls *Y. thraciaeformis*, but is smaller, without the angularity of that species and proportionately more solid. (Dall).

*Yoldia myalis* Couthouy, 1838. (Plate 1, fig. 8). Shell ovate, nearly equilateral, slightly gaping at both extremities, moderately convex, with numerous ridges of growth; summits antero-dorsal; posterior side rather more than half the whole length, posterior-superior margin somewhat depressed, inferior rounded; anteriorly sub-rostrate, not truncated, slightly compressed laterally and superiorly; anterior dorsal area lanceolate, smooth, shiny, carinated and rectilinear in its whole extent from the beaks to the extremity; posterior dorsal area superficial, elliptical and finely striated; basal margin regularly curved and entire; ligamentary fossa median, triangular and profound; teeth from 20-22, posteriorly rectilinear, angulated anteriorly or internally and slightly inclined to the summits; color of the interior dull yellowish-white; muscular impression well defined, bi-partite, the anterior one rounded or oval, posterior subtriangular; epidermis thin, smooth, dark olive with paler zones interposed between the incremental lines. (Couthouy). Length 27, height 17 mm. Off San Juan Island, Wash., in 25 fathoms.\*—Arctic Ocean to Puget Sound; Atlantic.

*Yoldia limatula* Say, 1831. (Pl. 12, Say's Amer. Conch.; pl. 1, fig. 9, Hanley's Monog. Nuculidae). Shell transversely ovate, very much elongated, thin, lines of growth very minute, otherwise smooth and covered with a beautifully glazed, light green epidermis, with an occasional darker zone, and two or three lighter radiations; beaks nearly central, not prominent, inclined backwards; hinge-margin behind rectilinear nearly to the tip, compressed, the compression not reaching the tip, which is a little recurved, pointed, not truncated; anterior and basal margin almost regularly rounded, entire; anterior bluish-white, somewhat pearly; cartilage-pit small; the series of teeth extending more than two thirds the length of the shell, is slightly bent at the pit; teeth prominent, most so at the middle of each side, their summits forming a regular arch. 22 on the anterior and 18 on the rostrated side, excavated on their outer faces; impressions quite obvious. Length, 1.9; height, 0.9; diameter, 0.5 inch. (Gould Invert. Mass.) Off Matia Island, Wash., in 35 fathoms.\*—Arctic Ocean to San Diego, Calif.; Atlantic.

*Yoldia scissurata* Dall, 1898. Plate 1, fig. 3). Shell rather small, oval, compressed, very thin, translucent, only slightly narrowed posteriorly; umbones minute, slightly anterior to middle, the anterior margin is evenly convex; a thin lamina runs along the anterior margin from the umbo to the end of the shell, a small much narrower one also occurs on the posterior margin; surface sculptured concentrically as in *Y. cooperi*, except that this incised sculpture is not in harmony with the incremental lines; hinge and teeth similar to *Y. cooperi*. Length, 20.4; height, 10; diameter, 4 mm. (Dall). Off Matia Island, Wash., in 35 fathoms.\*—Arctic Ocean to Puget Sound.

*Yoldia ensifera* Dall, 1897. (Plate 1, fig. 2). Shell large, thin compressed, with a brilliant olivaceous periostracum usually showing darker and lighter zones; valves nearly equilateral, moderately convex, rostrate, subarcuate; sculpture of fine lines of growth more or less evident, and on the anterior two-thirds of the shell numerous irregularly fluctuating, distant, incised grooves (like those of *Y. scissurata*) which are absent on the posterior third; base arcuate, anterior dorsal profile rounded evenly from the beaks; a slight inward wave of the margin is visible anteriorly near the pedal gape; lunule absent; the escutcheon impressed, and the posterior dorsal margins of the valves projecting vertically, blade-like, and slightly pouting; rostrum pointed, slightly recurved; beaks low, inconspicuous; valves internally whitish; pallial sinus deep, rounded; chondrophore wide, hardly projecting; teeth narrow, V-shaped, slender, about 30 in front of and 24 behind

the chondrophore. Length, 30; height, 15; diameter, 6 mm. (Dall). Off East Sound, Wash., in 25-35 fathoms.\*—Southeastern Alaska to San Luis Obispo, Calif.

*Yoldia seminuda* Dall, 1871. Shell obscurely lozenge-shaped, elongate, covered with a polished, glossy, olivaceous epidermis. Valves compressed, umbones inconspicuous; lunule long, narrow, just evident; escutcheon long, narrow, indented, well defined. Ventral margin arcuated, widest about the middle of the shell; a slight obsolete groove or channel anteriorly, bordered by two obscure ridges, terminates in a slight waved indentation in the anterior ventral margin, about the middle of the anterior fourth. Posterior end rising obliquely, rounded truncate posteriorly, forming an angle of 90° with the hinge margin, and slightly upturned. Posterior dorsal slope slightly concave, anterior slightly convex, evenly rounded to the anterior end. Ligament pit large, roundly triangular. Anterior teeth 37, posterior 17. Pallial sinus reaching before the umbones, which are 14.35ths of the whole length from the posterior end. Interior bluish-white, with fine radiating lines. Exterior marked by lines of growth and obsolete radiating lines; sculptured by sharp grooves, which, beginning near the middle of the shell with a slight wave toward the umbones, pass backward and downward across the lines of growth, rising a little and ceasing abruptly at a distance of about 4.35ths of the whole length from the posterior end. Length, 1.74; height, .82; diameter, .27 inch. (Dall). Victoria, B. C., by Dr. C. F. Newcombe.—Okhotsk and Bering Seas to Vancouver Island.

*Yoldia lanceolata* Sowerby. Shell thick, subventricose, oblong-sublanceolate, subcompressed, sculptured with curved, oblique, rather distant sulci in front and in the middle, covered with a strong epidermis; posterior side rather short, dorsal margin sloped, end widely truncated, rostral area smooth, slightly radiately angular; anterior side rounded at the end. (Conch. Iconica). Length about as in the last. Victoria, B. C., by Rev. G. W. Taylor.—Alaska to Vancouver Island.

#### MALLETIA Desmoulins, 1832

Shell oval, compressed, smooth or concentrically furrowed, epidermis olive; ligament external, elongated, prominent; hinge with an anterior and posterior series of fine sharp teeth; interior subnacreous; pallial sinus large and deep; anterior adductor giving off a long oblique pedal line. Type *M. norrisii* (Sby.)=*M. chilensis* Desm.

*Malletia faba* Dall, 1897. (Plate 45, fig. 13). Shell ovate, smooth,

slightly inequilateral, inflated, thin, covered with yellowish olive, brilliantly polished periostracum; beaks full, but not elevated, nearer the posterior end; anterior end rounded, dorsal and ventral margins nearly parallel; posterior end shorter, slightly more pointed; surface smooth or marked only by feeble lines of growth; a feebly impressed line may be regarded as the boundary of a lanceolate escutcheon, which is not impressed; internally bluish-white, a small high pallial sinus reaches nearly to the vertical of the beaks; hinge plate very narrow; the ligament very small and black, is wholly external and posterior; there are about nine small posterior teeth, the anterior teeth are still smaller and shorter and number about 32. Length of shell, 22.5; height, 13; diameter, 9 mm. (Dall). Off Queen Charlotte Islands, in 876 fathoms.—Queen Charlotte Islands to Lower California.

**TINDARIA** Bellardi, 1875

Shell thick, globose, oval, closed, beaks swollen; anterior teeth stronger, but the posterior row longer. Type *T. arata* Bellardi, Pliocene; Asti, Italy.

*Tindaria gibbsi* Dall, 1897. (Plate 45, fig. 12). Shell small, thin, subequilateral, inflated, with a polished pale olive periostracum and smooth surface; anterior end shorter, rounded; posterior end very slightly recurved; beaks full, not acute, base arcuate; ligament wholly external, amphidetic, discontinuous below the beaks; interior bluish-white, with a large round pallial sinus; anterior teeth 17, posterior 19, the line separated by a vacant triangular space on the hinge plate below the beaks. Length, 10; height, 6.5; diameter, 3.5 mm. (Dall). Off Queen Charlotte Islands in 876 fathoms.—Queen Charlotte Islands to Coronado Islands, Lower California.

**Family AROIDAE**

**GLYCYMERIS** Da Costa, 1778. (Pectunculus)

Shell orbicular, nearly equilateral, smooth or radiately striated; umbones central, divided by a striated ligamental area; hinge with a semicircular row of transverse teeth; adductors subequal; pallial line simple; margins crenated inside. Type *Arca glycymeris* Linne. (Arnold).

*Glycymeris subobsoleta* Carpenter, 1864. Shell similar to *G. septentrionalis*, slightly inequilateral, not tumid; umbones obtuse, broad, quite prominent, ash colored, variegated with reddish chestnut;

epidermis thick, somewhat laminated; ventral and posterior margins quite rounded, anterior margin produced, dorsal straight, sculptured by subobsolete radiating grooves, often disappearing dorsally; ventral margin strongly, and anterior and posterior internal margins slightly crenulated; cardinal plate subangular, with a few strong, compressed teeth; adductor scar chestnut colored; ligament furrowed. (Packard). Length 40, height 36, diameter 17 mm. Griffin Bay, off San Juan Island, Wash., in 30-35 fathoms.\*—Aleutian Islands to Puget Sound.

*Glycymeris migueliana* Dall, 1916. Shell solid, white with sparse zigzag lines of reddish brown and internally often with a touch of brown near the posterior margin; surface smooth except for irregularities of growth; valves suborbicular, anterior side slightly longer, posterior hardly produced; beaks low, area small and divaricately grooved; inner basal margin crenulated; anterior teeth 10-14, posterior 9-12; valves moderately convex. Length, 23; height, 22; diameter, 14 mm. (Dall). Near Departure Bay, Vancouver Island, by Dr. C. M. Fraser.—Vancouver Island to Magdalena Bay, Lower California.

### Family PHILOBRYIDAE

#### PHILOBRYA Carpenter, 1872

Shell like a minute Pinna, with pointed beaks; upper margin straight, with a strong internal ligament, anteriorly at the byssal sinus somewhat insinuated, ventrally and posteriorly rounded and gaping; posterior muscular scar subcentral, indistinct. The animal is stated to be viviparous; and in form like a minute Pinna, or a transverse Margaritophora without ears, or a Pinna without pits. (Carpenter).

*Philobrya scitosa* Carpenter, 1864. (Pl. 1, fig. 1, and text figs. 1, 4, Jour. de Conchyl. Vol. 5). Shell small, regular; ash colored, salmon or chocolate. Inside somewhat pearly with exquisite tints. Young shells flat, half round, straight along the back, equilateral, and conspicuously dotted. Nearly full grown shells rather transparent; adults rather solid with straight umbos which are terminally deeply hollowed inside. Dorsal margin rather short and straight. Front edge straight; ventral and posterior margins widely rounded. Externally the shell is clothed with a rather spongy epidermis; with somewhat distant rows of bristles which form an elegant comblike fringe at the edges. Inside the solid ligament is stretched along the dorsal edge; the mantle marking runs down from it to an even distance from the edge of the shell. The scar of the adductor muscle



is near the center and not conspicuous. The posterior end is gaping; the front is wavy on account of the slender byssus. (Carpenter). Length 13, width 2, height 2 mm. Off Alert Bay, B. C., by Rev. G. W. Taylor.—Forrester Island, Alaska, to Gulf of California.

### Family OSTREIDAE

OSTREA Linne, 1758

Shell irregular, attached by the left valve; upper valve flat or concave, often plain; lower convex, often plaited or foliaceous, and with a prominent beak; ligamental cavity triangular or elongated; hinge toothless; structure subnacreous, laminated, with prismatic-cellular substance between the margins of the laminae. (Tryon S. S. Conch.) Type *O. edulis* Linne.

*Ostrea lurida* Carpenter, 1864. Shell rather thin, darkly glaucous, rather smooth, lightly plicated near the ventral margin; mostly produced posteriorly; lower valve deep, dorsal margin narrow; upper valve nearly equal in extent to the under, slightly convex. (Carpenter in Conch. Iconica). Length 45, height 66, diameter 18 mm. Lagoon on Blakeley Island, Wash., by Dr. S. H. Brode; Van Dormer Creek, Vancouver Island.\*—Sitka, Alaska, to Cape San Lucas, Lower California.

### Family PECTINIDAE

PECTEN Mueller, 1776

Shell suborbicular, regular, resting on the right valve, usually ornamented with radiating ribs; beaks approximate, eared; anterior ears most prominent; posterior side a little oblique; right valve most convex, with a notch below the front ear; hinge margins straight, united by a narrow ligament; cartilage internal, in a central pit; adductor impression double, obscure; pedal impression only in the left valve, or obsolete. (Arnold). Type *P. islandicus* Mueller.

*Pecten* (Chlamys) *hericius* Gould, 1850. (Plate 23, figs. 1, 2). Shell triangular-ovate, longer than broad, equilateral or a little oblique and equivalve; valves rather full, especially near the beaks, whose sides rise abruptly from the ears; color rose-red, paler and zoned with deeper red beneath; everywhere covered with fine radiating lines, which are rendered rough by erect and arched spines. There are about 24 radiating ribs. On the upper side these are alternately large and small, the larger ones crowned along the ridge by a line of long,

erect, hollow spines; on the lower valves the ribs are nearly equal, the striae are coarser, and all the ribs are armed with a row of spines, though not so long as those on the upper valve. Ears oblique, very unequal, rayed with coarse, squamose striae. Interior porcelain-white, roseate at the edge, where it is finely crenulate. Length, 40; height, 47; diameter, 12; hinge 19 mm. (Gould). Plentiful off San Juan Island, Wash., in 20-35 fathoms.\*—Port Althorp, Alaska, to San Diego, California.

*Pecten* (Chlamys) *hindsii* Carpenter, 1864. (Plate 23, figs. 3, 4). Shell smaller than *P. hericius*, margins smooth. Right valve with about 26 close-set, sometimes wide, flattish, usually dichotomous, smooth ribs, which show fine lines of growth on their surfaces; interspaces narrow, channeled, and sculptured by minute reticulations; hinge line half as long as disk; anterior ear produced, sculptured by about 6 radial and prominently imbricating concentric lines; byssal notch prominent; posterior ear small, and with radial and imbricating concentric structure. Left valve with small, obscurely fasciculating, imbricated ribs, each fascicule having one major and several much smaller and more prominently imbricated riblets; interspaces very narrow and sculptured as in right valve; ears similar to those of right valve except lacking notch in anterior one. Color pink to white, the left valve being darker. Length, 58; height, 57; diameter, 18; hinge line, 29 mm. (Arnold). Plentiful at all the stations, in 20-30 fathoms.\*—Bering Sea to Cape St. Lucas, Lower California.

*Pecten* (Chlamys) *hindsii kincaidi* I. Oldroyd, 1910. (Plate 9, figs. 3, 4). Shell suborbicular, the height and length being nearly equal, equivalve, both valves slightly convex; ears as in *P. islandicus*; base evenly rounded; color yellowish-white with reddish-brown markings. Left valve with 28 narrow round-topped imbricated ribs, and very faint intercalaries, the interspaces wider. Right valve with 25 broader flat-topped ribs, some of which are divided toward the margin. Anterior ear (the larger) with 7 ribs, the posterior ear with 5 ribs. This species resembles *P. jordani* Arnold, but the valves do not tend to contract suddenly at the base as in *P. jordani*, and the right ear is larger. The ribs on the right valve of *P. jordani* are all divided from near the umbones. Length 38, height 40, diameter 13, hinge line 18 mm. Off San Juan Island, Wash., in 25 fathoms.\*—Puget Sound.

*Pecten* (Chlamys) *hindsii novarchus* Dall, 1898. (Plate 26, figs. 2, 3). Shell averaging about 55 millimeters in altitude, higher than

long, subequivalve, both valves only slightly ventricose, thin, sides only slightly concave above. Right valve light colored, less ventricose than left, with numerous small, subangular, flat-topped, dichotomous, and slightly imbricated ribs; surface obscurely tessellated; anterior ear quite prominent, with about 6 prominent radiating ridges and numerous imbricating incremental lines; byssal notch of medium size; posterior ear small, with distinct radial and imbricating sculpture. Left valve reddish or pinkish, more ventricose than the right, with numerous small fasciculated and quite prominently imbricated ribs, each fascicule having one prominent rib in the middle with lesser ones on the sides; the major interspaces occupied by a small riblet; ears as in right valve except lacking byssal notch. Margins not prominently serrate. Length, 55.5; height, 54; diameter, 21; hinge line, 17 mm. (Arnold). Off San Juan Island, Wash., with other *Pecten*.\*—Bering Sea to San Diego, Calif.

*Pecten* (*Chlamys*) *islandicus* Mueller, 1776. (Plate 24, figs. 1, 2). Shell suborbicular, somewhat higher than long, subequivalve; both valves only slightly convex, equilateral except for ears, of medium thickness; sides only slightly concave above; base evenly rounded; color of living shell pinkish to salmon, the left valve being the most highly colored. Right valve with numerous narrow, square, flat-topped, imbricated ridges, which multiply slowly, both by division and intercalation, as the shell grows; interspaces narrow, channeled, and minutely reticulated; hinge line equal to more than one-half length of disk; anterior ear much produced, sculptured by numerous sharp imbricating lines and 5 or 6 major radiating ridges and some intercalaries; byssal notch quite prominent; posterior ear a little over half as long as the anterior, and sculptured in the same way. Left valve similar to the right, except possibly that the imbrication is a little more pronounced. Length 77, height 83, diameter 27, hinge line 44 mm. (Arnold). Off San Juan Island and entrance to East Sound, Wash., in 25-35 fathoms.\*—Arctic Ocean to Puget Sound; Atlantic; Kamchatka.

*Pecten* (*Chlamys*) *islandicus pugetensis* Oldroyd, 1920. (Plate 9, figs. 5, 6). Shell much smaller than the typical, sculpture coarser in proportion to the size. More elongate and the ribs spinose. Ribs 17, with a very fine one in the interspaces. Length 29, height 31, diameter 11, hinge line 16 mm. Off San Juan Island, Wash., in 10-20 fathoms; shore at very low tide, fastened to rocks by the byssus; rare.\*—Puget Sound.

*Pecten* (Chlamys) *jordani* Arnold, 1903. (Plate 2, figs. 1, 2). Shell shape of *P. islandicus*, averaging about 45 mm. in altitude, somewhat shorter than high, inequivalve; both valves convex, equilateral except for ears, rather thin, and with smooth margins. Right valve with about 25-30 angular, smooth topped, imbricated ribs, which become dichotomous after reaching a length of about 30 mm.; interspaces deeply channeled and narrower than ribs; anterior ear imperfectly radially ribbed with 6 ridges, and showing elevated, concentric incremental lines; posterior ear nearly obsolete, showing about 4 ribs; byssal notch not deep. Left valve with 25-30 narrow convex ribs, showing imbricating sculpture only slightly; interspaces as wide as or wider than ribs; after a diameter of 30 mm. has been reached by the left valve small intercalary ribs appear in most of the widening interspaces; anterior ear with 5 narrow, imbricated ridges separated by wide interspaces. Both valves show a tendency to contract suddenly at the basal margin upon nearing completion of growth; surface of both valves covered with a minute lattice-like sculpture, which is generally worn off on exposed portions of the shell. Alt. 45; long. 42; hinge line 18 mm.; diameter 15. (Arnold). Described from a fossil and not found living before. Off San Juan Island, Wash., in 25-35 fathoms, in 1918, alive.\*

*Pecten* (Patinopectin) *caurinus* Gould, 1850. (Plates 25, 26; fig. 1). Shell large, rather thick, nearly circular, a little inequilateral and slightly oblique; the valves unequal; the upper valve is purplish-red, slightly convex, marked with delicate lines of growth, and with 20 or more slightly raised, rounded ribs, about half as wide as the interspaces, diminishing toward the sides, and sometimes nearly subdivided by one or more furrows; the lower valve more convex, white, and becoming reddish toward margins, and with about 22 ribs; these equal to the interspaces, elevated, flattened at summit, and with the sides vertical, and even incumbent, sometimes there are obsolete intervening ones. The ears are transverse, nearly equal, the anterior ones faintly rayed with scattered lirae; the sinus broadly rounded; beaks roseate, compressed; interior milk-white, with a silky lustre and roseate marginal limb. Length,  $2\frac{3}{4}$ ; breadth,  $2\frac{1}{4}$ ; height, 1 inch. (Gould). Off O'Neal and Orcas Islands, Wash., in 25-30 fathoms; off Victoria, B. C., by Dr. C. F. Newcombe.—Wrangell, Alaska, to Siletz Bay. Ore.

*Pecten* (Pseudamusium) *randolphi* Dall, 1897. (Plate 4, fig. 7). Shell small, thin, glassy, unsculptured, except by minute (camptorectes) striation which covers both valves, and more or less obscure

concentric undulations which are most distinct on the right valve near the umbo and in some specimens altogether absent; hinge straight and short; anterior ears distinct; posterior ears not defined by any fold or sinus; outline suborbicular; valves compressed, especially the right one; right anterior ear with 6 small imbricated radii above, below a wide, transversely striated fasciole derived from a well marked byssal sinus; ctenolium with 4 or 5 functional spines. Alt. 27.5; lat. 26; diam. 5 mm. (Dall). Off entrance to East Sound, Wash., in 35 fathoms; in Departure Bay, B. C.\*—Bering Sea to Guaymas, Mex.

*Pecten* (*Pseudamusium*) *vancouverensis* Whiteaves, 1893. (Plate 4, fig. 8). Shell small, equivalved, compressed lenticular, both valves being equally convex, ovately suborbicular in outline apart from the ears and rather oblique; valves extremely thin and fragile, translucent and almost transparent, pale horn color with a slightly yellowish hue. Beaks placed a little behind the midlength; hinge line straight and very long; ears unequal in size, the posterior pair, which are much smaller than the anterior, alike, indistinctly defined and merging gradually and imperceptibly into the general convexity and marginal contour of that side of each valve; anterior ears large, subtriangular, prolonged laterally and longer than high, distinctly defined, that of the left valve somewhat convex in outline above and concave below, that of the right valve with a deep acutely angular byssal sinus at its base. Surface marked by densely crowded and exceedingly minute, irregular and rarely continuous, but on the whole radiating, simple or bifurcating raised lines, also by comparatively large, regularly disposed and distant squamose radii. In the centre of each valve the minute and non-squamose raised lines are essentially parallel to the larger squamose radii, but on the sides the former are disposed obliquely to the latter. The surface of the anterior ear of each valve is minutely cancellated with extremely minute raised lines, which are almost parallel to the hinge line, in addition to the coarse cross lines. The whole sculpture of the exterior of the test is far too minute to be clearly seen without the aid of a microscope or powerful simple lens, but under either of these a few faint concentric lines of growth are also visible. (Whiteaves). Length 7.75, height 7.50, diameter 2.25 mm. Off Gabriola Island, near Nanaimo, B. C., by Dr. C. M. Fraser.\*—Bering Sea to San Diego, California.

*Pecten* (*Propeamusium*) *alaskensis* Dall, 1871. (Plate 27, fig 6). Shell nearly equilateral, inequivalve, flesh color, with a blush of salmon color on the umbo of the superior valve. Internally white, the salmon color showing through the valve. Shell suborbicular, barring the

auricles, which are wide and prominent. Lower (or right) valve flattened, 0.1 inch (2.5 mm.), smaller than the upper one; sculpture of fine, close, equal, concentric ridges, sharply defined and separated by narrow non-canalculated grooves. Valves covered with a fine velvety epidermis, ashy and very finely radiately striate. Surface of valve, except for the ridges, smooth. Anterior auricle long, prominent, with a deep sinus. Posterior auricle small; both with strong elevated lines of growth, which rise into scales on the 8 or 9 fine ribs with which the anterior auricle is furnished. Hinge line straight, smooth. Inside of the valve polished, furnished with 21 rounded radiating ribs, with traces of others intercalated near the margin; nodulous or swollen at the more prominent ridges of growth and at the margin. Upper valve similar, inside; anterior auricle shorter, not so deeply sinuated; valve more convex than the under one, and a little larger. Dorsal areas finely granulate. Umbo smooth; half way toward the margin the striae of increase become more conspicuous, and about 35 pseudoribs radiate toward the margin. These are formed by the elevation of the concentric lines of growth like ruffles, in such a way that the edge of one fluting of the ruffle overhangs the beginning of the next, and so on. These are very fragile, and when broken away show the nearly smooth surface of the valve underneath, without any true rib at all. Faint ribs are intercalated between the pseudoribs toward the margin. Length, .76; height, .76; diameter, .22 inch. (Dall). Lone Inlet and Rose Spit, B. C., in Rev. G. W. Taylor's collection.\*—Alaska to Vancouver Island.

#### HINNITES, Defrance, 1821

Shell inequivalve, adhering, thick, rather ponderous; valves slightly auriculated, radiately ridged. Hinge area in both valves broad, toothless, with a rather deep oblong pit in the middle. Muscular impression very large, sublateral. Differs from *Pecten* in its irregular growth, and in being adherent. (Conch. Iconica). Type *Hinnites cortesi* Defrance, 1857.

*Hinnites giganteus* Gray, 1825. (Plate 30, figs. 1a, 1b). Shell averaging about 75 millimeters in altitude, usually not quite so long as high, irregular, inequivalve, generally inequilateral on account of attachment to irregular surface; shell quite thick; margins smooth. Right valve more ventricose than left, ornamented by 9 to 18 narrow, irregular, prominently squamose ribs, between which in the flat interspaces are less prominent raised lines similarly sculptured; hinge line more than one-half length of disk; ears subequal, and more or less prominently sculptured by fine, squamose, radiating lines; byssal sinus some-

what visible. Left valve less ventricose than the right, otherwise similar. Hinge rather narrow and heavy; fosset deeply excavated, oblique, narrow, and angular; hinge is dark purple in living specimens. (Arnold). Young shell free swimming, later becoming attached to some fixed object. If this object has an irregular surface, the shell grows irregular in consequence. The young when free swimming are hard to distinguish from the young of a Pecten. Length 70, height 65, diameter 35, hinge line 40 mm. Fisherman's Bay of Lopez Island, Wash.\*—Aleutian Islands to Magdalena Bay, Lower California.

### Family LIMIDAE

LIMA (Bruguiere) Cuvier, 1798

"Shell equivalve; cartilage external; muscular scar placed on one side." (British Conch. Jeffreys). Lima and Pecten have nearly the same characters, but the value or importance of generic, as well as of specific differences is comparative and varies in each case. In the present genus the animal has a bright uniform color, while the shell is always white. Both animal and shell in the other genus are more highly favored in this respect and exhibit various hues. The Lima moves or rather darts through the water like a scallop, but in a contrary position. The hinder instead of the ventral end is in front, so that the mode of its progression may be compared to that of a fish swimming tail foremost. (Jeffreys Brit. Conch.)

*Lima* (*Limatula*) *subauriculata* Montagu, 1808. (Plate 1, fig. 10). Shell ovate-oblong, pellucid, white, equilateral, equivalve, furnished with small, equal, angular projections, or sub-auricles, and wrought with numerous longitudinal striae that slightly crenate the margin; along the middle are two striae that appear more conspicuous than the rest by being opaque, and are equally evident on the inside; a character constant in several specimens examined. Length  $\frac{1}{4}$  of an inch; breadth half its length. (Montagu). Off entrance to Departure Bay, B. C., in 40 fathoms, by Dr. C. M. Fraser.\*—B. C. to San Quentin Bay, Lower California.

### Family ANOMIIDAE

PODODESMUS Philippi, 1837

Valves radiately grooved; perforation of lower valve moderate, firmly embracing and enclosing the plug. (Tryon S. S. Conch.) Type *P. rudis* Broderip.

*Pododesmus* (*Monia*) *macroschisma* Deshayes, 1839. (Plate 35, figs. 1a, 1b). Shell ovate, rather solid, radiately rudely plicately ribbed; ribs very irregular, here and there swollen and bifurcated; yellowish-white; perforation very large. Length, 70; height, 68; diameter, 15 mm. (Conch. Iconica). Found around Puget Sound in 15-40 fathoms.\*—Bering Sea to Lower California; Japan; Okhotsk Sea.

### Family MYTILIDAE

#### MYTILUS Linne, 1758

Shell wedge-shaped, rounded behind in the typical species; umbones terminal, pointed; hinge-teeth minute or obsolete; pedal muscular impressions 2 in each valve, small, simple, close to the adductors. (Tryon S. S. Conch.) Type *M. edulis* Linne, 1758.

*Mytilus californianus* Conrad, 1837. (Plate 46, Fig. 6). Shell pyriformly elongated, slightly arched, solid, radiately ribbed, intermediate grooves conspicuously excavated, concentrically rudely wrinkled, posterior area smooth; yellowish-olive, blackish-blue with age. Length, 115; height, 45; diameter, 41 mm. (Conrad). General in San Juan County, Washington.\*—Unalaska, Alaska, to Socorro Island, off Mexico.

*Mytilus edulis* Linne, 1758. (Plate 46, fig. 1). Shell obliquely triangular, concentrically striated, blue-black, olive, rayed with black, rather compressed posteriorly, anteriorly arcuately impressed. Length, 55; height, 24; diameter, 18 mm. (Conch. Iconica). General along shore in San Juan County, Wash.\*—Arctic Ocean to Cerros Island, Lower California; worldwide in temperate waters.

#### MODIOLUS Lamarck, 1799

Shell oblong, inflated in front; umbones anterior, obtuse; hinge toothless; pedal impressions 3 in each valve, the central elongated; epidermis often produced into beard-like fringes. (Tryon S. S.) Type *M. modiolus* Linne, 1758.

*Modiolus modiolus* Linne, 1758. (Pl. 1, fig. 2, Conch. Iconica, as *Modiola*). Shell oblong, somewhat trapeziform, ventricose toward the umbones, smooth or obsoletely wrinkle-striated; dark chestnut. Length, 100; height, 45; diameter, 32 mm. (Conch. Iconica). Off San Juan Island, Wash., in 25-35 fathoms.—Bering Sea to San Pedro, Calif.; circumboreal.

*Modiolus flabellatus* Gould, 1850. (Plate 25, fig. 2). Shell large,



thin, elongate, trapezoidal, dilated posteriorly; beaks elevated, pyramidal, contiguous, acute, placed at the anterior seventh; umbonal ridge elevated, angular above, widening and becoming more rounded backwards; portion anterior to the slope trigonal, wedge-shaped in 3 directions; extremely narrow, rounding upwards; dorsal and ventral margins diverging, rectilinear for three-fourths of length, when the upper margin rounds downward; posterior extremity broadly rounded; epidermis glossy, first triangular third of a scorched, dark chestnut-brown or tar-color, palest at extremity; posterior third pale yellowish-horn color; behind the umbonal ridge rigid with a coating of loose fringe-like terminations of the layers of growth; interior pearly white; slightly gaping in front. Length, 150; height, 50; diameter, 38 mm. (Gould). Off San Juan Island, Wash., in 20 fathoms.\*—Vancouver Island to San Diego, Calif.

BOTULA Moersch, 1853

Shell oblong, subrhomboidal, subcylindrical; beaks distant, sub-terminal.

*Botula californiensis* Philippi, 1847. (Pl. 5, fig. 19, Martin & Chemnitz's Conchylien Cabinet, 2nd Ed., as *Lithophaga*). Shell cylindrical, lithophagus-like, smooth, very thin, somewhat pointed, sub-nacreous, white, posterior end sometimes tinged with blue; epidermis shining, smooth, thick, dark brown; young shells typically modiolarae-form, umbones directed anteriorly; anterior dorsal margin slightly crenulated; adult shell with dorsal and ventral margins nearly parallel; anterior and posterior margins rounded; umbones worn, not conspicuous, situated about one-sixth the distance from the anterior to posterior extremity; incrustation thin, porous, covering the posterior area diagonally, prolonged beyond the valve;; internal ligament prolonged posteriorly; inner surface pale; posterior adductor scar large, circular, impressed; with a subumbonal callosity, conspicuous toward the pedal scar. Length, 40; height, 10; diameter, 11 mm. (Packard). Vancouver Island, B. C.—Vancouver Island to San Diego, Calif.; Japan.

MODIOLARIA Beck, 1840. (Musculus)

Shell rhomboidal, sculptured by two rows (one on each side) of the striae which radiate from the beaks, leaving the middle portion smooth; beaks incurved; hinge mostly toothless, but sometimes crenulated; hinge-plate finely notched. Type *M. impacta* Herm.

*Modiolaria laevigata* Gray, 1824. (Plate 3, fig. 5). Shell oblong-ovate, broader anteriorly, rather compressed, everywhere concentric-

cally striated, slightly excavated in the middle, posterior extremity obscurely grooved; olive-chestnut, horny, shining. This species constructs a nest and lives among the clumps of mussels. Length, 35; height, 21; diameter, 16 mm. (Conch. Iconica). Off San Juan Island, Wash., in 20-30 fathoms; Victoria and Nanaimo, B. C.\*—Arctic Ocean to Puget Sound.

*Modiolaria nigra* Gray, 1824. (Plate 3, fig. 6). Shell somewhat squarely ovate, rather compressed, anteriorly densely finely striated, smooth in the middle, posteriorly ridged at the extremity, purple black. This species does not construct a nest. Length, 21; height, 15; diameter, 6mm. (Conch. Iconica). Off San Juan Island, Wash., in 25-35 fathoms; Victoria and Nanaimo, B. C.—Arctic Ocean to Oreg.; circumpolar.

*Modiolaria corrugata* Stimpson, 1851. Shell oval, tumid, upper edge somewhat compressed and arching, posterior tip somewhat produced and pointed; beaks large, nearly terminal; surface with about 16 ribs at the anterior third, and very numerous ones at the posterior third. Length, 20; diameter, 8 mm. (Gould Invert. Mass.) North arm of Burrard Inlet, B. C., by Dr. C. M. Fraser.\*—Arctic Ocean to Puget Sound.

*Modiolaria marmorata* Forbes, 1838. (Fig. 84, Gould's Invert. Mass., as *Musculus*). Shell obliquely rhomboidal, very gibbous, obtusely angled, rayed posteriorly and anteriorly with grooves and ridges, smooth in the middle; greenish-ash, tinged with rose. (Conch. Iconica). Puget Sound.—Puget Sound; circumboreal.

*Modiolaria taylora* Dall, 1897. (Pl. 1, figs. 17, 18, Bull. Nat. Hist. Soc. Brit. Columbia, No. 2). Shell small, rather solid, modioliform, with a greenish epidermis, and dark purple nacre shining through; inflated, with the middle area of the exterior of the valves impressed; beaks low, not quite terminal; surface smooth, except for lines of growth; the anterior area very small, with some obscure radial striae; the middle area smooth, its basal margin pouting a little; posterior area covering more than half the shell, swollen; ligament obscure, almost internal; margins of the valves smooth, except for some small denticulations on a thickened area below the beaks, and a few beyond the distal end of the ligament. Length, 5.5; height, 3; diameter, 2.5 mm. (Dall). Tide pools at Victoria, B. C.\*—Vancouver Island, B. C.

*Modiolaria olivacea* Dall, 1916. Shell small, thin, polished, pale olivaceous near the beaks, growing darker distally; medial area

smooth, anterior area with 6 or 7 rather strong radial grooves; posterior area with numerous shallow channeled radii crossed by rather regular slightly elevated concentric lines, giving a silky luster to the surface; beaks inconspicuous, inflated; dorsum arched, base nearly straight, both ends evenly rounded, the posterior slightly wider; interior whitish, the margin crenulated by the sculpture, the beaks very close to the posterior end. Length, 10; height, 6; diameter, 5 mm. (Dall).---Bering Sea to Catalina Island, Calif.

CRENELIA Brown, 1827

Shell oval or rhomboidal, nacreous, cancellated; umbones straight; ligament small; hinge of each valve furnished with an upright tooth which is crenulated, as well as the hinge-plate. Type *C. decussata* Montagu.

*Crenella columbiana* Dall, 1897. (Plate 3, fig. 7). Shell large for the genus, inflated, elongated oval, thin, of a delicate greenish-gray tint, usually somewhat stained by blackish blotches; umbones conspicuous, prisogyrus, terminal; surface of the shell entirely covered with fine radiating threads, like those of *C. decussata*, but proportionally more delicate; concentric sculpture only of delicate incremental lines; margin of the valves extremely thin and denticulate; a small portion immediately under the beaks thickened; ligament rather long, deep-seated, hardly visible, close to the margin. Extreme length, 16; height, 12; diameter, 9.5 mm. (Dall). Off Lopez Island, Wash., in 20-25 fathoms.\*—Aleutian Islands to San Diego, Calif.

*Crenella decussata* Montagu, 1808. (Pl. 45, fig. 2, Forbes & Hanley's Brit. Mollusca, vol. 2). Shell obliquely oval, with a slight approach to a rhomboidal form when viewed sideways, rather solid, somewhat glossy and prismatic; sculpture 50-60 fine longitudinal ribs, crossed by 40-50 transverse striae; the former resemble those of the last species, *C. rhombea* Berkely; the latter are thread-like and form minute nodules or beads on the ribs at the points of intersection; colour pearl-white: epidermis rather thick and yellowish-brown: margins rounded on all sides except at the back, where an obtuse angle separates the hinge-line: beaks globular and prominent, placed close to the anterior margin, over which they slightly project; they are quite smooth, with the exception of some delicate transverse striae: ligament thick, reddish-brown: hinge-line nearly straight: hinge-plate rather broad, finely crenulated: hinge toothed as in the last species: inside nacreous, showing more or less distinctly the impression of the ribs; inner margin notched all round: scars more perceptible than in *C.*

*rhombea*, owing to the greater thickness of the inner coat of nacre. Length, 0.15; breadth, 0.12 inch. (Jeffreys Brit. Conch.) Off San Juan Island, Wash., Victoria and Departure Bay, B. C.\*—Bering Sea to San Pedro, Calif.

### Family THRACIIDAE

#### THRACIA Blainville, 1824

Shell concentrically striated, with more or less fine superficial granulation and a very delicate periostracum, subrostrate, slightly gaping behind; slightly inequivalve, the right valve larger; the beaks in contact and usually perforated by friction on each other, the hinge-plate fissured below them and edentulous; the ligament external, the resilium more or less sunken and with, in most cases, a short, transverse lithodesma in front of it, occupying the fissure in the hinge-plate; pallial line with a moderate sinus, margins of the valves entire; the nymphs in the typical forms do not project greatly from the hinge-margin ventrally and are more or less elongated; the shell destitute of nacre. (Dall). Type *T. corbuloides* Blainville.

*Thracia curta* Conrad, 1837. (Plate 7, fig. 4). Shell subovate; anterior margin obtusely rounded; posterior margin direct, subrectilinear; umbonal slope angular. Length, 30; height, 20; diameter, 13 mm. (Conrad). Off San Juan Island, Wash., in 25-35 fathoms; Departure Bay, B. C.\*—Icy Cape, Alaska to San Diego, Calif.

*Thracia trapezoides* Conrad, 1849. (Plate 7, fig. 2). Shell thin, smooth, except for incremental lines which become sublamellose on the posterior dorsal area; valves slightly unequal, nearly equilateral, moderately convex, with an umbonal ridge bounding the lower side of the posterior dorsal area, in front of which the valves are slightly concave; dorsal slopes subequal, anterior end rounded, posterior squarely truncate; base arcuate, a little prominent in the middle. Length, 48; height, 38; diameter, 16 mm. (Dall). Off O'Neal and Lopez Islands, Wash., in 20-25 fathoms; sponge beds, Departure Bay, B. C.\*—Puget Sound; Pliocene of Calif.; Miocene near Seattle, Wash.

*Thracia challsiana* Dall, 1915. (Plate 7, fig. 1). Shell large, chalky, subquadrate, almost equivalve, the posterior end longer; surface covered with a coarse, almost imbricating granulation, without radial elevations or defined dorsal areas. Both ends are rounded, there is no distinct posterior truncation, though that end is blunter than the anterior; resilium and ligament marginal, inconspicuous, with no

indication of a lithodesma; pallial sinus wide, shallow, reaching only half way from the posterior end to the vertical of the beaks. Length, 45; height, 33; diameter, 20 mm. (Dall). Off Lopez Island, Wash., in 25 fathoms, Sponge beds, Departure Bay, B. C.\*—Forrester Island, Alaska to Monterey, Calif.

*Thracia beringi* Dall, 1915. (Plate 7, fig. 3). Shell of moderate size, white, with a dehiscent yellowish periostracum (usually lost), and looking much like a *Macoma sabulosa*. Valves nearly equal, nearly equilateral, with low beaks and a conspicuous external ligament enfolding the resilium. Surface with incremental irregularities and in the periostracum numerous small wrinkles, but without perceptible granulation. Pallial sinus large, rounded, not reaching the vertical from the beaks. Valves rounded at both ends, the posterior dorsal area inconspicuous, not bounded by a rib, and there is no indication of a lithodesma. Length, 35; height, 25; diameter, 12 mm. (Dall). Departure Bay, B. C., young (?), by Rev. G. W. Taylor.\*—Bering Sea to Puget Sound.

### Family PANDORIDAE

PANDORA Hwass, 1795

Shell inequivalve, thin, pearly inside; valves close, attenuated behind; right valve flat, with a diverging ridge and cartilage furrows; left valve convex, with two diverging grooves at the hinge; pallial line slightly sinuated. (Tryon S. S. Conch.) Type *P. rostrata* Lamarck.

*Pandora* (Kennerlia) *filosa* Carpenter, 1864. (Plate 37, figs. 2a, 2b). Shell small, plano-convex, elongate-oval, thin; umbones minute, about one-fourth length from anterior extremity; anterior and posterior dorsal margin straight, making an angle of 160 degrees at the umbo; ventral margin arcuate; posterior extremity long, narrowed and truncated at the end; anterior rounded up from the base but making an angle with the dorsal margin; a single prominent posterior, submarginal ridge runs from the umbo to the extremity of each valve, being nearer the margin in flat valve; surface of both valves sculptured by numerous fine, concentric, incremental lines, and that of the right valve by fine radiating sulcations; left valve with a thin hinge ossicle; right valve with two ossicles, the anterior one being short. Length, 16; height, 7; diameter, 3 mm. (Arnold). Off Orcas Island, Wash., in 25 fathoms; common in Departure Bay, B. C.\*—Nunivak Island, Bering Sea, to San Pedro, Calif.

*Pandora* (Kennerlia) *grandis* Dall, 1877. (Plate 4, fig. 3). Shell large, plano-convex, not rostrate, dorsal margin of the convex valve angulated with reference to the longitudinal axis of the shell, as well as bent over the umbo of the flat valve so as to completely overshadow it. Convex valve externally smooth except for lines of growth, chalky, somewhat twisted. From the umbo an incised line passes to the ventral margin where it ends; the portion of the ventral margin behind the point marked by the end of this line extends ventrally some distance beyond the limit reached by that portion anterior to it. The anterior portion is equal to the flat valve, which closes upon it; the posterior portion extends beyond the edge of the flat valve so much that in life it appears as if a part of the anterior ventral margin had been broken or cut out. The outer surface of the anterior area bounded by the incised line has also its lines of growth more regularly distributed, giving the appearance of light concentric sculpture, and usually retains the epidermis longer than the remainder of the valve, which is more convex. The interior of this valve is livid pearly, sparsely punctate, and with the spectral grooves radiating from the hinge teeth. These are so faint that they can be seen in some lights, but not felt. They correspond to the points of attachment of the mantle. The flat valve has the ventral margin rather evenly curved, with no sinus. The dorsal margin is bent over at a right angle behind the hinge, and angulated at the umbo. The surface is marked by an area corresponding to that on the convex valve, and with a similar striation, but not separated from the rest by an incised or any other definite line. Behind the area thus marked, the flat valve is a little concave, marked by faint, concentric waves and radiating, irregular lines, marked on the shell by a light groove, but carrying a raphe of epidermis; interior pearly, with the anterior tooth very strong. Length, 2.2 inch; depth, hinge to ventral margin of convex valve before the sinus, 1.5 inch; behind the sinus, 1.04 inch; diameter, 0.38 inch. (Dall). Off San Juan Island, Wash., in 20-35 fathoms.\*—Unalaska, Alaska, to Siletz Bay, Oreg.

*Pandora* (Kennerlia) *glacialis* Leach, 1819. (Plate 4, fig. 2). Shell broad, rather short, ventricose, rather thick, wrinkled concentrically; anterior side with a very slight corner, impressed with a slightly radiating groove, sinuated at the margin; posterior side broader, very shortly beaked, obtuse, rayed near the margin with two rather nodulous ribs, convex at the ventral margin; left valve deep, without teeth; right valve with one tooth; cartilage inserted

in a pit; thickened at the sides with a calcareous layer. Length, 30; height, 20; diameter, 7 mm. (Leach). Off Lopez Island, Wash., in 15-20 fathoms.\*—Arctic Ocean to Puget Sound.

*Pandora* (Kennerlia) *bilirata* Conrad, 1855. (Plate 5, fig. 25, Pacific R. R. Repts., vol. 6). Shell oblong, very inequilateral, contracted anteriorly, convex medially; posterior side with two distant cardinated lines toward the hinge margin which is straight and not oblique; posterior extremity truncated. Length, 14; height, 8 mm. (Conrad). Off Vancouver Island, by Rev. G. W. Taylor.\*—Forrester Island, Alaska, to Point Abrejos, Lower California.

*Pandora* (Heteroclidus) *punctata* Conrad, 1837 (not Carpenter, 1864). (Pl. 17, fig. 1, Journ. Acad. Nat. Sci. Philadelphia, vol. 7). Shell expanded, broad, arched; anterior side short, margin with a slight corner above the middle, inside with impressed-punctures rayed with a single tooth distant from the margin; posterior side produced, expanded, slightly beaked, raised at the end, acuminate; dorsal margin depressed in a curve; left valve expanded at the ventral margin. Length, 30; height, 17 mm. (Conch. Iconica). Off Vancouver Island?—Vancouver Island to Gulf of California.

### Family LYONSIIDAE

LYONSIA Turton, 1822

Shell nearly equivalve, left valve largest; thin, subnacreous, close, truncated posteriorly; cartilage plates oblique, covered by an oblong ossicle; pallial sinus obscure, angular. (Arnold). Type *L. norvegica* Chemnitz.

*Lyonsia californica* Conrad, 1837. (Pl. 19, fig. 20, Journ. Acad. Nat. Sci. Philadelphia, vol. 7). Shell of medium size, elongate-oval, truncated and narrowing slightly, posteriorly convex, thin, long, slightly depressed posteriorly to umbo; short, convex anteriorly; surface sculptured with fine concentric, incremental lines; external layer chalky and fugacious, pearly beneath; cartilage plates oblique, covered by an oblong ossicle; pallial sinus obscure. Length, 31; height, 14; diameter, 11 mm. (Conrad). Off Orcas Island, Wash., in 30 fathoms; off Matia Island, Wash., in 25 fathoms.\*—Puget Sound to Todos Santos Bay, Lower California.

*Lyonsia pugetensis* Dall, 1913. (Plate 2, fig. 3. Shell large, thin, pearly under a thin olivaceous gray periostracum which is covered with fine radial lines to which fine sand adheres strongly, so that an

attempt to remove the sand destroys the greater part of the periostracum; the shell is slightly inequivalve and very inequilateral, the anterior end being much the shorter; the periostracum projects over the shelly margin; the anterior end is evenly rounded, the posterior rostrate; the beaks not conspicuous; the base is convexly arcuate in the middle but is rapidly attenuated toward the rostrum, which is terminally truncated; interior pearly, pallial area relatively small within the somewhat irregular unsinuated pallial line; hinge edentulous with a small narrow lithodesma. Length, 50; height, at the beaks 22; diameter, 10 mm. (Dall). Off East Sound, Wash., in 35 fathoms.\*—Chignik Bay, Alaska, to Puget Sound.

*Lyonsia striata* Montagu, 1815. (*Lyonsia bracteata* Gould, 1850). (Pl. 13, fig. 1A, Trans. Linn. Soc., vol. 11). Shell extremely thin and fragile, translucent, pearly, nacreous and reflecting golden colors internally, and somewhat externally; form oblong-ovate, inequilateral, somewhat recurved; beaks acute, at the anterior third; anterior end obtusely rounded; posterior end triangular-elliptical, broadly truncated at tip, the basal portion, where the umbonal slope attains, being notably ventricose; basal margin at this part depending; anterior dorsal edge arcuate; posterior dorsal rectilinear, compressed. Surface covered with a dusky epidermis of considerable firmness, which is corrugated into numerous, delicate, radiating, raised wrinkles, to which a coating of fine sand adheres. Hinge too imperfect for description. (Gould). Gould's description is given because Montagu's was inaccessible. Length, 18.75; height, 9.38 mm. Puget Sound.\*—Aleutian Islands, Alaska, to the Strait of Fuca; circumboreal.

*Lyonsia gouldii* Dall, 1915. (*Lyonsia nitidum* Gould). (Pl. 15, fig. 6, Gould's Mex. and Calif. Shells). Shell transverse, subfalcate, ventricose and thin with a bright pearly lustre, undulate concentrically and for the most part destitute of epidermis; apex situated at one third of the length from the front; front end rounded, posterior end narrowed, truncate and somewhat ascending; each end is furnished with distant radiating lines. (A free translation from Gould). Length 19, height 10 mm. Near the Ballenac Islands in the Strait of Georgia, by C. M. Fraser.\*—Vancouver Island to Point Abreojos, Lower California.

*Lyonsia* (*Entodesma*) *inflata* Conrad, 1837. (Pl. 19, fig. 10, Journ. Acad. Nat. Sci. Philadelphia, Vol. 7). Shell subelliptical, inflated; concentric rugae distinct; ligament margin concave; basal margin gibbous; posterior extremity truncated; cardinal appendage



dilated. Length, 25; height, 13; diameter, 8mm. (Conrad). Vancouver Island, living on sponges.\*—Vancouver Island to Guayaquil, Ecuador.

*Lyonsia* (Entodesma)) *saxicola* Baird, 1863. Shell oblong-ovate, gibbous in the center, produced anteriorly, compressed posteriorly and gaping. The beaks are large and incurved; it is covered with an olive colored epidermis which is striated transversely. The ventral margin is gaping and flexuose. The substance of the shell, without being very thin, is exceedingly brittle and cracks very easily. The ossicle covering the front of the internal cartilage is strong and well developed. Length 100, height 50, diameter 35mm. Along shore, Olga, Orcas Island, Wash.; Puget Sound in general.\*—Aleutian Islands to Cape Colnette, Lower California.

Dall says "This enormous rude species, sometimes reaching nearly 6 inches in length, is by all odds the largest species of the family. The coarse, horny periostracum in drying always cracks the calcareous portion of the valves. Its nestling habits result in an infinite variety of distortions. The lithodesma is very large and strong and is inserted obliquely below the dorsal margin."

*Lyonsia* (Entodesma) *scammoni* Dall, 1871. (Pl. 16, fig. 3, Amer. Journ. Conch., vol. 7). Shell inequilateral, inequivalve, subovate. Left valve slightly the smaller. Shell tumid, umbones inconspicuous, nearly in the middle of the shell. Interior with a brilliantly pearly, white nacre; hinge margin narrow, nearly straight; interrupted under the beaks; right valve with a small rounded projecting process, fitting into an excavation in the opposite valve, which is thickened behind it. Ligament and ossicle moderate. Pallial line simple, continuous. Anterior margin evenly rounded; posterior ditto, a little more effuse; ventral margin with the faintest possible indication of flexuosity; shell gaping behind, but with no perceptible ventral gape. Exterior smooth except for lines of growth, which are more emphasized at intervals, forming 3 concentric waves from the umbo toward the margin. Shell covered with a thin yellowish brown pubescent epidermis, which is produced over the margins, and under a lens is seen to be very closely, finely, radiately striate. The pubescence is formed by little projecting points of the epidermis at the intersections of the striae with the lines of growth. Shell solid. Length, .9; height, .44; diameter, .33 inch. (Dall). Known only from Port Simpson, B. C., and San Diego, Calif.

## MYTILIMERIA Conrad, 1837

Shell equivalve, suboval, thin, beaks subspiral; hinge edentulous, with a slight linear cavity under the beaks; muscular impressions two, rather small; pallial impression with a broad obtuse sinus. (Conrad). Type *M. nuttallii* Conrad.

*Mytilimeria nuttallii* Conrad, 1837. (Pl. 19, fig. 5, Journ. Acad. Nat. Sci. Philadelphia, vol. 7). Shell suboval, inflated, thin, fragile; white with a very thin yellowish deciduous epidermis. Living in compound Ascidians. Length, 45; height, 38; diameter, 28 mm. (Conrad). Off San Juan Island, Wash., in 15-20 fathoms; Departure Bay, B. C.\*—Vancouver Island to San Diego, Calif.

## Family CUSPIDARIIDAE

## CUSPIDARIA Nardo, 1840

Shell globular, attenuated, gaping behind; right valve a little the smaller; umbones strengthened internally by a rib on the posterior side; cartilage process spatulate, in each valve (furnished with a movable ossicle) with an obsolete tooth in front and a posterior lateral tooth; pallial sinus very small. (Tryon S. S. Conch.) Type *C. cuspidata* Olivi.

*Cuspidaria* (*Cardiomya*) *californica* Dall, 1886. Plate 1, fig. 14; plate 42, fig. 3). Shell differing from *C. pectinata* by its smaller size and proportionally greater length; larger number of ribs (16-20), while *pectinata* averages (12-14); its straighter, longer rostrum with but two strong radiating lirae extending to the lower extreme: *pectinata* has none, or only several fine ones near the body of the valve); its less inflated shape and paler more delicate epidermis. Color yellowish white; ossicle as usual; buttress present in the right valve. Lon. of shell .7; of rostrum 2.5; alt. of shell 3.6; diameter 2.75 mm. (Dall). Dodds Narrows, B. C.\*—Departure Bay, B. C., to San Diego, Calif.

"*Cuspidaria* (*Cardiomya*) *oldroydi* n. sp., Dall. (Plate 1, fig. 13). Shell small, short, inflated, chalky white with a pale olivaceous periostracum; beaks prominent, rounded; valves slightly inequilateral, the left valve slightly smaller than the other, the body of the shell short-oval, the rostrum short, straight, abruptly truncate; sculpture of about 15 radial threads which extend over the whole valve except the rostrum; incremental lines feeble. Length of anterior end, 5.5;

of posterior end, 5; height, 7; diameter, 5mm. (Dall). Lopez Island, Wash.; Puget Sound.—Vancouver Island to Puget Sound.

"It is smaller when adult and more coarsely sculptured than young *C. planetica* or *C. balboae* of the same size, much larger and more inflated than *C. pectinata*, *C. californica* or *C. beringensis*, all of which belong to the same group, and superficially are very similar except in size." (W. H. Dall).

#### LEIOMYA A. Adams, 1864

An anterior prominence or cardinal tooth in each valve, anterior and posterior laterals in the right valve, left valve without laterals. Cartilage in a posteriorly directed groove or fossette; surface smooth or concentrically sculptured. (Dall). Type *Neaera adunca* Gould.

*Leiomya* (Plectodon) *scabra* Carpenter, 1864. Dorsal margins twisted-in spirally inside the unbo. Lateral teeth laminated, with internal cartilage hidden, appressed. Length, 17; height, 10; diameter. 9 mm. (Carpenter). In deep water, off Seattle, Wash., by Dr. G. D. Hanna.—Puget Sound to San Diego, Calif.

#### Family ASTARTIDAE

##### ASTARTE Sowerby, 1816

Shell suborbicular, equivalve, inequilateral, thick, compressed; hinge with two solid diverging teeth in the right valve, one tooth and a slight posterior elevation in the left; muscular impressions two in each valve, uniform, united by a simple impression; ligament external. (Sowerby Conch. Manual). Example *A. sulcata* Nilson.

*Astarte compacta* Carpenter, 1864. (Plate 16, fig. 4). Shell small, stout, trigonal, like *A. esquimalti* but with regularly arcuate, uniform concentric ribbing. Length, 12; height, 14; diameter, 5 mm. (Dall). Off Orcas Island, Wash., in 30 fathoms. Rare.\*—Forrester Island, Alaska, to Puget Sound.

*Astarte alaskensis* Dall, 1903. (Plate 3, fig. 9). Shell much resembling *A. elliptica* of the eastern coast, but shorter, heavier, and more trigonal. The periostracum is black or dark brown and dehiscent when dry. Length, 28; height, 31; diameter, 10 mm. (Dall). Off Orcas Island, Wash., in 30 fathoms.—Herchell Island, Arctic Ocean, to Puget Sound.

*Astarte fabula* Reeve, 1855. (Pl. 33, fig. 5, Belcher's Last of the Arctic Voyages, vol. 2). Shell ovate-subtrigonal, elevated, obliquely

tumid in the middle; anterior side obliquely produced, excavated under the umboes; umboes leaning backward, prominent, acuminate; posterior side sloped, very obscurely truncated, ventral margin sloped upward; concentric ridges near the umboes numerous, neat, sharp, becoming obscure at the middle and below. (Conch. Iconica). Length, 22; height, 17 mm. Off Vancouver Island, by Rev. G. W. Taylor.\*—Arctic Ocean to Vancouver Island; circumboreal.

A thin elongate-ovate, inflated species, with the posterior end slightly longer, the umbonal region peculiarly, squarely, concentrically sulcate, and the basal portion striated. The color is usually dark brown. It was described by Sowerby in 1874 as *A. semilirata*. (Dall). The first description is that of Sowerby for *A. semilirata*.

*Astarte esquimalti* Baird, 1863. (Plate 3, fig. 10). C. testa parva, cordato-trigona, crassiuscula, olivacea, transversim undatoplicata, antice producto-rotundata, postice subtruncata, margine ventrali rotundata, umbonibus prominulis, lunula longe caudata. Long. rather more than one-third inch; lat. one-half inch. (Baird). Off San Juan and Orcas Islands, Wash., in 25-30 fathoms.\*—Aleutian Islands to Puget Sound.

### Family CARDITIDAE

#### CARDITA (Bruguere) Lamarck, 1799

Shell oblong, radiately ribbed; ligament external; margins toothed; hinge-teeth 1-2, and an elongated posterior tooth; pallial line simple; anterior pedal scar close to adductor. (Tryon S. S. Conch.)

*Cardita subquadrata* Carpenter, 1865. (Fig. 152, Keep's West Coast Shells). Shell small, transverse, subrectangular, ventricose, thick; beaks subanterior, not prominent; dorsal posterior margin long, straight; anterior portion abruptly truncated just in front of beak; surface sculptured with heavy, squamose, radiating ridges; anterior margin coarsely crenulated; hinge with two lateral diverging teeth in each valve, the posterior teeth being in each case much elongated, the anterior short and pointed. (Arnold). Length, 6; height, 10; diameter, 5.6 mm. Queen Charlotte Islands.—Queen Charlotte Islands to Todos Santos Bay, Lower California.

#### VENERICARDIA Lamarck, 1801

Shell suborbicular, inequilateral, radiately ribbed; hinge with two oblique cardinal teeth and no laterals. (Tryon S. S. Conch.)

*Venericardia stearnsii* Dall, 1902. (Plate 46, figs. 9, 10). Shell short, plump, strong, with very high prosogyrate beaks and about 19 strong nodulous radial ribs with narrower interspaces and a dark-brown pilose periostracum. It has been taken for *V. ventricosa*. It is a much shorter and higher shell with a very small deeply impressed lunule and strong hinge, in which the lunular pustule in the left valve is conspicuous. Length, 15; height, 14; diameter, 7mm. (Dall). In 1200 fathoms.—Puget Sound to Santa Barbara, Calif.

*Venericardia ventricosa* Gould, 1850. (Plate 3, fig. 8). Shell small, subcircular, ventricose, thick; umbones slightly anterior to center, much bent forward, prominent; surface sculptured by about 13 prominent, rounded, radiating ridges, which are slightly roughened by regular lines of growth; sulcations narrow; hinge area broad, short; two prominent teeth in each valve, anterior short; margin closely crenulated. Length, 12.5; height, 13; diameter, 8 mm. (Gould). Off San Juan Island, Wash., in 30 fathoms.\*—Belkoffski Bay, Alaska, to Coronado Islands and Cortez Bank, Lower California.

*Venericardia* (*Miodontiscus*) *prolongata* Carpenter, 1864. (Plate 16, figs. 5, 6). "M. testa parva, solida, tumida, compacta, albida; ventraliter antice valde prolongata, excurvata; lunula longa, rectiore, haud impressa; umbonibus antice inflectis, obtusis, valde prominentibus; margine dorsali postico parum excurvato; costis radiantibus x.-xii. latis, obtusis, marginem attingentibus, parvum expressis, dorsaliter obsoletis, a liris incrementi concentricis, plus minusve distantibus, expressis, hic et illic interruptis; intus, margine a costis plus minusve obsoletim crenulato; cardine dentibus v. dextr., uno postico, inter duas fossas elongato, et lat. ant. lunulari; v. sinistr., dent. ant. triangulari, post. valde elongato, lat. ant. minmo, obsoleto; cicatr. add. subrotundatis, ventraliter sitis." (Carpenter).

Shell small, high, the anterior end longer, with narrow umbones and radial ribbing, a well-marked lunule and escutcheon present, the hinge with the right cardinal absent and a posterior right and anterior left lateral feebly developed. Length, 5; height, 5; diameter, 3 mm. San Juan Island, in gravel; also dredged in shallow water.\*—Middleton Island, Alaska, to San Diego, Calif.

### Family THYASIRIDAE

THYASIRA (Leach in) Lamarck, 1818

Shell globular, posterior side furrowed or angulated, umbones much recurved; lunule short or indistinct; ligament usually and to

a certain extent external, placed in a groove on the hinge-line, and outside the hinge-plate; teeth altogether wanting. (Arnold). Type *Tellina flexuosa* Montagu.

*Thyasira bisecta* Conrad, 1849. (Plate 6, fig. 1). Shell oblique, subrhomboidal, ventricose, with robust lines of growth. Anterior side very short, truncate, angulate below, having a submarginal vertical furrow, and the inferior margin at its termination slightly excavated. Posterior surface strongly excavated from the upper side of the beak to the posterior margin, and subcarinate below the excavation; ligament and supero-posterior margin forming together a regular curve. Basal margin arcuate, a little tumid behind the middle. Length, 85; height, 74; diameter, 45 mm. (Conrad). Off Brown Island, Wash., in ooze or thin mud, in 3 fathoms; very rare.\*—Off Alaskan Peninsula to Puget Sound.

*Thyasira barbarensis* Dall, 1889. (Pl. 8, fig. 9, Proc. U. S. Nat. Mus., vol. 12). Shell white, superficially chalky, rather compressed. rounded below, the beaks not very prominent; the surface is sculptured only with incremental lines; there is a rather large impressed lunular area not circumscribed by a line; behind there is an upper, narrow and deep radial depression with a lower, wider and less marked second one, which makes corresponding flexuosities of the posterior margin; a narrow rather deep groove runs near the margin outside the ligament marking off a narrow elongate escutcheon; interior white, unpolished; hinge edentulous. Length, 5; height, 5; diameter, 3 mm. (Dall). Off San Juan Island, Wash., in 3-10 fathoms; shore of Turn Island, Wash. Rare.—Straits of Fuca to Gulf of California.

*Thyasira gouldii* Philippi, 1845. (Plate 42, fig. 5). Shell minute, white, ovate-globose or somewhat triangular, nearly equilateral; beaks prominent, inclined forwards, and having a rounded depression in front of them; behind them a remarkable widened groove runs near the margin to the posterior base, producing a deep indentation in the outline of the margin at that part; elsewhere regularly rounded; surface smooth, dead white. Hinge with only the vestige of a cardinal tooth and no lateral ones. Ligament long and rather large, partly concealed. Interior glossy white, with minute radiating lines. Length, 3-10 of an inch; height, somewhat more; width, 1-10 of an inch. (Gould Invert. Mass.) Puget Sound (?).—Bering Sea to San Diego, Calif.; Atlantic.

## AXINOPSIS G. O. Sars, 1878

Shell discoidal, tumid in the middle, compressed toward the margins; umbones slightly prominent; no external ligament; valves thin, pellucid, white, concentrically striated; cardinal tooth in the right valve obtusely elevated, recurved, in the left valve obtusely elevated, subhorizontal; cartilage narrow. (Tryon S. S. Conch.) Type *A. crebiculata* Sars, 1878.

*Axinopsis sericatus* Carpenter, 1864. (Plate 26, fig. 4). Shell small, circular, flat; epidermis silken. Length, 5; height, 5; diameter, 4 mm. (Carpenter). Off Brown and Turn Islands, Wash.; Departure Bay, Vancouver Island.\*—Aleutian Islands to Catalina Island, Calif.

## Family DIPLODONTIDAE

## DIPLODONTA Bronn, 1831

Shell subcircular, smooth; ligament double, rather long, submarginal; hinge teeth 2-2, of which the anterior in left valve, and posterior in the right are bifid; muscular impressions polished, anterior elongated. Type *D. lupina* Brocchi.

*Diplodonta orbella* Gould, 1852. (Plate 3, fig. 4; plate 25, figs. 5, 6). Shell small, subglobose, beaks nearly median, not prominent; surface sculptured with fine incremental lines, which at some parts are more conspicuous than at others and render the surface somewhat irregular; no distinct lunule; ligament prominent; 2 cardinal teeth in right valve, of which the anterior is the smaller, and the posterior bifid; and 2 in the left valve, of which the anterior is bifid and the posterior very oblique; no lateral teeth; muscle impression large, faint. Length, 11.9; height, 11.9; diameter, 9 mm. One specimen off San Juan Island, Wash.; plentiful in Hood Canal, Wash.\*—Pribilof Islands, Bering Sea, to Gulf of California.

## Family LUCINIDAE

## PHACOIDES Gray, 1847

Shell lentiform, with strong dorsal areas and chiefly concentric sculpture, the cardinal teeth obsolete in the adult, but the laterals well developed. (Dall).

*Phacoides* (*Lucinoma*) *annulatus* Reeve, 1850. (Plate 37, figs. 5, 5b). Shell orbicular, rather flattened, inequilateral, concentrically laminately ridged; ridges sharp, erect; interspaces concentrically stri-

ated; lunule lanceolately ovate, rather deeply excavated; semitransparent white. Length, 50; height, 54; diameter, 17 mm. Turn Island, Wash., at low tide on sandy beach.\*—Port Althorp, Alaska, to Coronado Islands, Lower California.

*Phacoides* (Parviluncina) *tenuisculptus* Carpenter, 1865. (Plate 3, fig. 14; plate 37, figs. 1a, 1b). Shell small, orbicular, deeply convex, thin; umbones prominent, central surface sculptured by numerous fine, concentric lines and radiating striae; lunule prominent, the greater part being in the right valve; cardinal teeth small, laterals prominent; anterior muscle impression not as elongated as in *P. acutilineatus* and others. Length, 11; height, 13; diameter, 9 mm. Off O'Neal and Shaw Islands, Wash., in 25-30 fathoms.\*—Nunivak Island, Bering Sea, to Coronado Islands, Lower California.\*

### Family LEPTONIDAE

#### KELLIA Turton, 1822

Shell round and inflated, concentrically striated or smooth; with an obsolete external ligament and a large internal resilium, without a lithodesma; 2 anterior and 2 posterior teeth in each valve, of which the anterior ones are shorter and may be con crescent or free and postular; interior of valves commonly shows radial striation, and valves frequently distorted. (Arnold). Type *K. suborbicularis* Montagu, 1804.

*Kellia laperousii* Deshayes, 1839. (Plate 6, fig. 2; plate 37, fig. 4). Shell of medium size, suborbicular, convex, thin; umbones slightly anterior, not prominent; surface sculptured by fine incremental lines which are slightly variable as to prominence; no lunule; each valve with one very prominent cardinal tooth; right valve with 2 posterior laterals, left with one; hinge-area lacking between cardinal and lateral teeth; muscle impressions not distinct. (Arnold). Length, 25; height, 22; diameter, 16 mm., a large specimen. Orcas and San Juan Islands, Wash.\*—Bering and Pribilof Islands, Bering Sea, to San Diego, Calif.

*Kellia suborbicularis* Montagu, 1804. (Pl. 26. fig. 6, Montagu's Testacea Brit.; also pl. 11, figs. 5, 6, Turton's Dithyra Brit.) Shell small, suborbicular, deeply convex, thin, beaks small, slightly anterior; surface ornamented with fine lines of growth which become somewhat irregularly constricted near the margin, roughening the surface; no lunule; margins smooth; hinge and teeth as in *K. laperousii*.



Length, 8.4; height, 7.4; diameter, 5.8 mm. (Arnold). Off San Juan Island, Wash.\*—Bering Sea to Panama; Atlantic.

ROCHFORTIA Velain, 1846

Shell ovate or rounded-trigonal, periostracum adherent, usually polished; individuals free or domiciliary in the burrow of crustaceans. (Dall).

*Rochfortia tumida* Carpenter, 1864. (Pl. 87. fig. 7, Proc. U. S. Nat. Mus., vol. 21). Shell subelliptical, both ends broadly rounded, lines of growth fine, ossicle minute. Length, 3; height, 3.1; diameter, 1 mm. Orcas and Turn Islands, Wash., along shore.\*—Shumagin Islands, Alaska, to San Diego, Calif.

PSEUDOPYTHINA Fischer, 1884

Shell rather large for the family, reniform, with a coarse rugose periostracum; hinge with two projections of the right dorsal margin fitting into sulci of the opposite valve, one right and one left cardinal, a strong internal resilium, sometimes with a lithodesma, and an evident but small external ligament; laminae absent or not distinct. Type *Kellia macandrewi* Fischer.

*Pseudopythina rugifera* Carpenter, 1864. (Plate 27, figs. 8, 9). Shell large, thin, slightly indented; teeth minute; epidermis shaggy. Commensal with Gebia. (Carpenter). Length, 14; height, 9; diameter, 6 mm. Off San Juan Island, Wash., in 20-30 fathoms; Comox Spit, B. C., by Dr. C. M. Fraser.\*—Vancouver Island to Puget Sound.

*Pseudopythina compressa* Dall, 1899. (Plate 4, fig. 1). Shell large, subquadrate, thin, moderately compressed, white, covered with a conspicuous, thin, wrinkled, partly glossy periostracum; nearly equilateral, the posterior end slightly broader, both ends rounded, the basal margins nearly straight; beaks inconspicuous, surface with strong, irregular incremental lines, but no radial sculpture; pallial scar rather wide and irregular, merging into the subequal, rather narrow adductor scars; resilium large, wide and long, more or less calcareous ventrally, left valve with one obscure cardinal tooth, right valve with the tooth better developed; the right dorsal valve margins overlap those of the left valve a little, but there are no distinct lamellae. Length, 18; height, 13; diameter, 6 mm. (Dall). Comox Spit, B. C., by Dr. C. M. Fraser. Commensal with Crustacean.\*—Cape Lisburne, Arctic Ocean, to Acapulco, Mex.

*Pseudopythina myaciformis* Dall, 1916. Shell small, myaciform, plump, nearly equilateral, the posterior end slightly shorter, wider and rounder; anterior end more attenuated; surface finely concentrically

threaded, but obscured by an habitual coating of a blackish color, probably manganese dioxide; the shell underneath it is yellowish white; hinge weak, ligament carrying a long, very narrow lithodesma. Commensal with Crustacean. Length 8.5, height 5.5, diameter 3 mm. (Dall). Port Orchard, Wash.—Puget Sound.

#### LASAEA Leach, 1827

Shell minute and roundish oval; beaks straight; cartilage long, placed at the shorter end of the shell, contrary to that in *Kellia*; left valve with a minute thorn-like cardinal tooth; and in each valve 2 remarkably strong teeth. (Tyron S. S. Conch.) Type *L. rubra* Montagu.

*Lasaea rubra* Montagu, 1804. (Pl. 27, fig. 4, Montagu's Testacea Brit.; pl. 11, figs. 7, 8, Turton's Dithyra Brit.) Shell minute, rather thick, suboval, very inequilateral, rather compressed; beaks rather prominent and in contact, having before them a deeply excavated, elongated, smooth areola; ends broadly rounded, especially the posterior tip; basal margin scarcely curved and nearly parallel with the superior margin; surface marked with the lines of growth, eroded at the beaks, and covered with a purplish or dirty-brown rather thick epidermis. Within white and glossy; two muscular impressions, the pallial line directly connecting them, without any sinus, quite perceptible. Hinge consists, in the right valve, of a narrow, erect, central tooth, and an imperfect one on each side, slightly detached from the edge of the valve; in the left valve, of a well-defined tooth on each side, barely separated from the edge of the valve, leaving a triangular vacancy between them to receive the central tooth of the opposite valve. Length about 2, height 1, diameter 2 mm. Turn, Orcas and San Juan Islands, Wash.\*—Vancouver Island to Callao, Peru.

Below is given the description from Montagu's Testacea Britannica, 1804, as *Cardium rubrum*: C. with a convex, smooth, glossy, pellucid, red shell: hinge not quite central; rather broader than it is long, rounded at both ends: umbo prominent; hinge with nearly obsolete primary teeth; lateral ones very conspicuous. Inside glossy red; margin plain. A minute species not exceeding the eighth of an inch in breadth.

#### TURTONIA Alder, 1848

Shell oblong, inequilateral, anterior side very short; ligament concealed between the valves; hinge-teeth 2-2. In pools and crevices of rocks between tide-marks, and in the roots of sea-weeds and coral-lines. (Tryon S. S. Conch.) Type *T. minuta* Fabricius.

*Turtonia minuta* Fabricius, 1780. (Pl. 18, fig. 7, Forbes & Hanley's Brit. Mollusca, vol. 2). Shell very minute, ovate, rather convex, fragile, semi-transparent, beaks at about the anterior third, elevated, inclined forwards, smooth and somewhat shining; straw-colored, blending into dark purple at the beaks and posterior slope; depressed in front of the beaks so that the anterior portion is less elevated than the posterior, then passing round in a regular elliptical sweep into the ventral margin, which is very gently curved; posterior dorsal margin very nearly straight, toward the end sweeping somewhat more rapidly than the ventral margin, so that the end is sharper than the front end, and the point below the median line. The anterior dorsal margin dilates a little so as to form a triangular jutting just under the beak, and there sometimes appears a more minute one by the side of it; and there appears to be a very minute furrow along the posterior edge, not seen without a powerful magnifier. Colors of the interior like those of exterior; pallial line without a notch. (Gould Invert. Mass.) Length about 2.1, height 1.67, breadth 1.25 mm. Gulf of Georgia.—Bering Strait to Magdalena Bay, Lower California.

### Family CARDIIDAE

#### CARDIUM Linne, 1758

Shell ventricose, close or gaping posteriorly; umbones prominent, subcentral; radiately ribbed; margins crenulated; pallial line more or less sinuated. (Tryon S. S. Conch.) First species *C. costatum* Linne.

*Cardium* (Cerastoderma) *corbis* Martyn, 1784. (Plate 42, figs. 1a, 1b). Shell large, subtrigonal, ventricose, thick; umbones prominent, anterior to center; surface ornamented with about 37 prominent, irregular, squarish, closely set, radiating ridges, which are made more or less rugose by incremental ridges on their surface; near the posterior margin these ridges become more rounded and less prominent; between the ridges are equal, deep, canal-like grooves; margins crenulated; ligament short, external, prominent; each valve with one prominent cardinal tooth, and 2 laterals, one anterior and the other posterior; muscle impressions prominent, subequal. (Arnold). Length 71, height 71, diameter 57 mm. Lopez and San Juan Islands, Wash.; Mudge Island, Gulf of Georgia.\*—Bering Sea to San Diego, Calif.; Japan.

*Cardium* (Cerastoderma) *californiense*, Deshayes, 1841. (Plate 16, fig. 3). Shell small, thin, ventricose, yellowish-white, a thin epidermis, adhering closely; posterior umbonal slope a little angular; beaks prominent, acute, incurved; surface sculptured with about 40

radiating ribs separated by narrow grooves, the ribs showing a little flattened. Length 40, height 41, diameter 26 mm. Off San Juan Island, Wash., in 25-35 fathoms.\*—Arctic Ocean to San Diego, Calif., and Japan.

*Cardium* (Cerastoderma) *fucanum* Dall, 1907. Shell small, plump, compact, solid for its size, covered with a smooth brown or gray periostracum usually more or less eroded; form varying from nearly circular to slightly ovate, with rather prominent slightly prosocoelous beaks, situated a little anterior to the middle of the shell; valves moderately convex, equal and nearly equilateral, sculptured with numerous (40-58) similar, small, low, flattish radial ribs separated by much narrower inter-spaces; these ribs are not nodulous nor keeled, they are sometimes slightly rippled by the incremental lines, and as usual, are smaller, fainter and more crowded distally; the interspaces are rounded; near the dorsal margins on each side of the beaks there is an ill-defined narrow space which is devoid of ribs; the average number of ribs is about 50; the inner margins of the valves are crenulated; the hinge delicate and normal; the inner surface of the valves white, polished; the outer surface usually shows three or four concentric sulci due to resting-stages. Length, 38; height, 33; diameter, 18 mm. (Dall). Off San Juan Island, Wash., with *C. californiense*.\*—Bering Sea to Monterey, Calif.

*Cardium* (Cerastoderma) *ciliatum* Fabricius, 1780. (*C. islandicum* Linne). (Fig. 150, Gould's Invert. Mass.) Shell large, rather thin, a little obliquely rounded-ovate, tumid; anterior part shortest and narrowest, ends regularly rounded; beaks prominent, the points turned inwards, and nearly in contact; in front of them is a narrow, heart-shaped depression; on each valve are 36 or more, 3-sided, sharp-edged, radiating ribs, the furrows between them rounded and regularly wrinkled by the lines of growth; epidermis yellowish-brown, lax and bristling into a stiff fringe on the sharp edge of the ribs; within straw colored, the portions covered by the mantle pearly; grooves answering to the ribs without, are obvious within, and the edges are strongly notched. Length, 2 inches; height, somewhat less; breadth, 1 inch. (Gould Invert. Mass.) Puget Sound.—Arctic Ocean to Puget Sound and northern Japan; circumboreal.

SERRIPES Beck, 1841

Shell subcordiform, compressed, subequilateral; surface smooth or slightly radiately striate; beaks prominent; cardinal and lateral teeth obtuse, small, almost obsolete. (Tryon S. S. Conch.) Type *S. groenlandicus* Gmelin, 1792.

*Serripes groenlandicus* Gmelin, 1792. (Plate 24, fig. 3). Shell large, not very thick, sub-triangular, elevated, rather compressed; beaks not very prominent, curved inward and slightly forward, nearly central; anterior margin regularly rounded; posterior part somewhat elongated; margin protuberant beyond the ligament, bordered by a slight wave, which gives the posterior termination a somewhat sinuous or truncated appearance and leaves the shell gaping at this point; this region is also more coarsely wrinkled than the rest; surface marked with minute lines of growth, divided into zones by darker indications of the stages of growth, which successive increments appear very loosely attached posteriorly; these are crossed by numerous inconspicuous, radiating ridges; epidermis thin, shining, of a drab or very light fawn-color; hinge slender; cardinal teeth nearly wanting; marginal teeth distinct but small; muscular and pallial impressions profound, within which the shell is opalescent-white, the margin light, salmon-color; edge slightly crenulated. Length, 3-4 inches; height, 2-3 inches; diameter, 1-2 inches. (Gould Invert. Mass.) Off Olga, Orcas Island, Wash., in 25-35 fathoms; Victoria and Departure Bay, B. C.\*—Arctic Ocean to Puget Sound; Japan.

#### PROTocardia Beyrich, 1845

Shell globose, with a posterior area sharply distinguished by sculpture from the rest of the surface; closed; hinge normal; no escutcheon or lunule. (Arnold).

*Protocardia centiflosa* Carpenter, 1864. (Plate 42, figs. 2a-2d). Shell small, suboval, ventricose, thin; umbones central, prominent, only slightly bent; surface sculptured by numerous fine, close-set, rounded, radiating ridges, which are made slightly rugose by numerous fine incremental lines on their surface; thin sharp teeth in each valve; pallial sinus shallow, wide; margin beautifully and sharply serrate. Length, 15; height, 15; diameter, 11 mm. (Arnold). Off O'Neal Island, Wash., in 25 fathoms; Departure Bay, Vancouver Island.\*—Vancouver Island to Lower California.

*Protocardia centiflosa richardsonii* Whiteaves, 1878. (Plate 16, fig. 7). This variety differs from *P. centiflosa* in being a little stronger and coarser, with which it seems to be united by intermediate gradations, though the extremes have apparently good distinctions. Size about as *P. centiflosa*. (Dall). Off O'Neal Island, Wash., with the above; Departure Bay, B. C.\*—Queen Charlotte Islands to San Francisco, Calif.

**Family VENERIDAE****TRANSENNELLA** Dall, 1883

Shell small, having the general form and coloration of *Tivela*, but a hinge with 3 cardinals in each valve, the middle left cardinal bifid, and elongated left lateral received into a socket in the opposite valve; the hinge has no rugosities, the lunule but not the escutcheon is defined, internal margins sharply tangentially grooved with numerous sulci; the pallial sinus angular, free, obliquely ascending. (Dall). Type *T. conradiana* Dall.

*Transennella tantilla* Gould, 1852. (Pl. 15, fig. 10, Boston Journ. Nat. Hist., vol. 6). Shell quite small, rather solid, ovate-trigonal, inequilateral; beaks acute; surface smooth or faintly waved with distant concentric furrows; the dorsal margins are nearly straight and meet at the apex in a right angle, but the posterior side is a fourth longer than the anterior; the anterior basal angle is well rounded, while the posterior is acute; basal margin gently curved. Color white, but the posterior third is stained deep slaty blue outside and in, the line of demarcation being quite abrupt and well defined; there is also a pencil of the same color inside, running from the beak to the anterior cicatrix; the rest of the interior is cream colored. Length, one-quarter inch; height, one-fifth inch. (Gould). Turn Island, Wash., among roots of eel grass; general.\*—Sitka, Alaska, to Lower California.

**SAXIDOMUS** Conrad, 1837

Shell transversely oval, inequilateral, solid, ventricose; without lunule; umbones tumid; teeth 3 or 4, unequal, narrow, the central bifid; ligament very thick, elongated; muscular impression oval or rounded, nearly equal; pallial sinus large, elongate, horizontal. (Conrad). Type *S. nuttallii* Conrad.

*Saxidomus giganteus* Deshayes, 1839. (Pl. 43, Guérin's Mag. de Zool. Mollusca, 1841; fig. 2, Bull. U. S. Fish. Comm., vol. 3). Shell solid, broad, heavy; the young are yellowish white; the adult attains a length of 130 mm. and the concentric sculpture is much less pronounced than in *S. nuttallii*. The exterior is sometimes fulvous, but the interior is always white. Length, 100; height, 60; diameter, 54 mm. (Dall). San Juan Island, Wash., and general on all the islands of the vicinity, in mud or sand.\*—Aleutian Islands to Monterey, Calif.

*Saxidomus giganteus brevis* Dall, 1917. Shell short, subtriangular, small in comparison with the type and much less elongated. Length, 60; height, 50; diameter, 33 mm. (Dall). San Juan Island,

Wash.; with the typical.\*—Admiralty Island, Alaska, to Tacoma, Wash.

VENUS (Linne) Lamarck, 1799

Shell solid and heavy, porcellaneous, and somewhat earthy; the periostracum extremely thin and hardly visible; the form is rounded or trigonal with faint radial striation and stronger concentric lamellosity; the inner margins are crenulate; the pallial sinus is small and triangular; the beaks are prominent; the lunule and escutcheon well defined; there are two bifid cardinal teeth in the left valve; one posterior bifid and two anterior simple cardinals in the right valve; a supplementary posterior cardinal in each valve below the ligamentary nymph is modified to form a rugose area of which the asperities interlock with those of the opposite valve. (Dall).

*Venus kennicottii* Dall, 1871. (Pl. 16, fig. 1, Amer. Journ. Conch., vol. 7; pl. 40, fig. 7, Proc. U. S. Nat. Mus., 24). Shell cuneiform, dark ferruginous brown, ornamented with fine concentric, slightly elevated lamellae. Valves rather inflated, thick; umbones prominent, rounded, within the anterior third; anterior end rounded from below to the lunule, which is broad, cordiform and impressed, bounded by a deeply incised line. Extreme anterior end of the valves rather pinched together. Anterior ventral margin arcuated. Posterior end thick, rather produced and pointed. Posterior side roundly arched from the umbones to the end; two obsolete carinae pass from the umbones on each side posteriorly, the inner pair forming the boundary of the ligamentary area. Inner posterior and ventral margin finely crenulated. Hinge line strongly arched behind. Dental area broad, teeth strong. Posterior dental process rugose. Muscular impression large; pallial sinus short, sharply angulated. Sculpture of fine concentric laminae, slightly elevated, more so on the anterior end, more distinct on the umbones, thickly crowded near the margin especially anteriorly. Lines of growth prominent at intervals. Lamellae passing over the ligamentary area and lunule. Interior white; the dark brown of the exterior may be a stain but looks natural. Lon. 2.64; alt. 2.1; diameter, 1.56 inches. (Dall). Neah Bay, Wash.; Port Simpson, B. C.—Port Simpson, B. C., to Little River, Mendocino County, Calif.

MARCIA H. & A. Adams

Shell large, subquadrate, concentrically lamellose and striated, without radial sculpture, and a dull, earthy surface; internal margin smooth; pallial sinus small, angular, free; hinge with 3 left and 4 right cardinals, the middle ones larger and grooved above. (Dall). Type *Venus exalbida* Dillwyn.

*Marcia kennerleyi* (Carpenter) Reeve, 1863. (Plate 24, fig. 4). Shell oblong oval, somewhat square, dull opaque white, concentrically plicately ribbed; ribs close-set, a little recurved, rather irregular; lunule and ligamentary area narrow. (Reeve). Length 80, height 60, diameter 40 mm. Off East Sound and in Griffin Bay, Wash., in 25-35 fathoms.\*—Kodiak Island, Alaska, to Carmel Bay, Calif.

*Marcia subdiaphana* Carpenter, 1864. (Plate 27, fig. 1; plate 37, fig. 4). Shell of medium size, oval, transverse, inequilateral, ventricose, rather thin; beaks small, incurved; anterior extremity quite sharply angulated about the middle of the shell; posterior extremity much longer and wider than anterior and very evenly rounded, projecting farthest a little below the middle; ventral margin evenly arcuate; surface sculptured by numerous fine, regular, concentric, incremental lines; neither lunule nor escutcheon, but a faint lunular circumscribing line in front of umbo; 3 prominent, sharp, cardinal teeth in each valve, the anterior one being narrower and longer than the other two; external ligamental groove long, narrow; pallial sinus cuneiform, rather deep. Length, 67; height, 53; diameter, 44 mm.; medium size specimen. (Arnold). Off San Juan and Orcas Islands, Wash.; not rare.\*—Sannak Islands, Alaska, to Santa Barbara Islands, Calif.

PAPHIA Bolten, 1798. (Including Tapes)

Shells compressed, elongate-ovate, smooth or feebly concentrically sculptured. (Dall). Type *P. alapapilionis* Bolten.

*Paphia* (Protothaca) *tenerrima* Carpenter, 1856. (Plate 31, figs. 1a, 1b). Shell large and thin, oval, convex; surface sculptured by numerous low, sharp concentric frills, and numerous fine, rounded, crowded, radiating lines, these later lines being almost obsolete in some specimens; margin smooth, hinge long and narrow; 3 teeth in each valve, the anterior 2 in the right valve and the middle one in the left valve prominently bifid; pallial sinus very deep and rounded; no lunule. (Arnold). Length 105, height 82, diameter 37 mm. Olga, Wash.\*—Puget Sound to San Quentin Bay, Lower California.

*Paphia* (Protothaca) *staminea* Conrad, 1837. (Pl. 19, fig. 15, Journ. Acad. Nat. Sci. Philadelphia, vol. 7). Shell suboval or sub-orbicular, convex, with numerous crowded radiating striae, and finer concentric lines, most distinct on the anterior side; posterior extremity direct; ligament margin nearly parallel with the base; color variegated with yellowish and brown, and with brown angular spots; cardinal teeth compressed; sinus of pallial impression profound. Length,



50; height, 42; diameter, 30 mm. (Conrad). Olga and San Juan Islands, Wash.; general all over Puget Sound; along shore.\*—Commander and Aleutian Islands to Socorro Island, Mex.; Japan.

*Paphia* (Protothaca) *staminea rudrata* Deshayes, 1853. The form, which is found chiefly in the north, is characterized by the turgidity and prominence of the concentric sculpture, which becomes more conspicuous than the radial ribs. The specimens are rude and irregular, coarse and unattractive. Size as typical. (Dall). San Juan Island, Wash., both on shore and dredged; Departure Bay, B. C., on shore.\*—Bering Sea, to Lobitas, Calif.

*Paphia* (Protothaca) *staminea petiti* Deshayes, 1839. (Pl. 39, Guérin's Mag. de Zool. Mollusca, 1841). Shell yellowish, chalky white or dull gray color without maculations, sculpture markedly separated into areas. (Dall). Length 60, height 55, diameter 35 mm. San Juan and Orcas Islands, Wash.; on shore.\*—Aleutian Islands to San Quentin Bay, Lower California.

*Paphia* (Protothaca) *staminea spatiosa* Dall, 1916. Shell large, heavy, rounded quadrate, inequilateral, the beaks behind the anterior end 18 mm.; yellowish or brownish white without markings; sculpture of simple, similar, narrow radial ribs with narrower interspaces, except on the posterior dorsal area where there are a few wider ribs with deeper interspaces; inner margins finely crenulate; pallial sinus deep, narrow, nearly horizontal. Length, 80; height, 67; diameter, 50 mm. (Dall). Puget Sound.—Puget Sound to Anaheim Bay, Calif.

*Paphia* (Protothaca) *staminea laciniata* Carpenter, 1864. (Pl. 14, fig. 5, Arnold's Palaeont. San Pedro). Shell large, oval, swollen, thick, but brittle; surface net-like, caused by prominent, thick, rounded, concentric frills, and numerous rounded, radiating ridges; margins smooth; hinge and interior parts as in *staminea*. (Arnold). Length 80, height 68, diameter 56 mm.—Unalaska, Alaska, to San Diego, Calif.

*Paphia* (Protothaca) *staminea orbella* Carpenter, 1864. (Plate 37, fig. 6). This variety comprises those specimens which have nestled in the borings of the large Pholads of the coast, and are obliged to grow into an abnormally swollen and tumid shape. They are usually chalky and of a gray tint. (Dall). Puget Sound.—Kodiak Island, Alaska, to San Diego, Calif.

#### LIUCYMA Dall, 1870

Shell small, white or unicolored, covered with a vernicose periostracum, and concentrically waved, without radial sculpture; lunule circumscribed, escutcheon absent; inner margins smooth; pallial sinus

short, free, rounded triangular; 3 cardinals in each valve, the anterior right and posterior right entire, the others bifid; siphonal tubes unequal, the anal shorter, both united to their tips; foot long and pointed, without a byssal groove; the manile open ventrally and smooth edged, (Dall). Type *Venus fluctuosa* Gould.

*Liocyma scammoni* Dall, 1871. (Plate 25, fig. 7). Shell most resembling *L. fluctuosa* but less compressed, much stouter and thicker. Epidermis of a deep yellow brown instead of waxen; shape more triangular with the posterior ventral margin more produced; umbones dark umber brown; ligament longer, stouter and much more prominent; lunule almost obsolete, with the waves continued over it instead of smooth. Concentric sculpture in waves, not separated by grooves as in *L. fluctuosa* of the same size, but further apart, more irregular and rounded or sharp instead of flattened. Hinge line broader, teeth larger and much stouter than in any other species; pallial sinus shallower and rounder, and muscular impressions proportionately larger than in any other form of the genus. Lon. .8; Alt. .84; diameter, .36 inches. (Dall).—Known only from Port Simpson, B. C.

#### GEMMA Deshayes, 1853

Shell rounded, subtriangular, subequilateral, smooth, margins crenulated within; hinge short and narrow; 3 teeth in the left valve, the middle one conical, arcuated; 2 divergent teeth and an intermediate pit in the right valve; pallial impression marginal, with a narrow, deep sinus. (Tryon S. S. Conch.) Type *G. gemma* Totten.

*Gemma gemma* Totten, 1834. (Fig. 2, Amer. Journ. Sci., vol. 26). Shell rounded-triangular, equilateral, sub-inflated, somewhat thick, pale purple and partly white, with transverse striae; beaks prominent, margins not crenulated. Introduced from the Atlantic coast with "seed" oysters. Length, 3; height, 3; diameter, 2 mm. (Packard). Turn, San Juan and Orcas Islands, Wash., along shore.\*—Puget Sound to San Francisco Bay, Calif.

#### PSEPHIDIA Dall, 1902

Shell small, vermiform, polished, with faint concentric sculpture; beaks not prominent; valves inequilateral, with a narrow, feebly defined lunule and no escutcheon; inner margins not crenulate; pallial sinus distinct, angular; hinge with 3 delicate cardinals in each valve, but no laterals. (Dall). Type *P. lordi* Baird.

*Psephidia lordi* Baird, 1863. (Plate 25, fig. 3). It is a small species, of an ovate-triangular shape, a smooth shining appearance; and a light olive color. The surface is concentrically marked with

slight grooves. The beaks are prominent and very shining. Internally the surface is white, the margins of the shell very faintly crenulate and the pallial impression short and blunt. (Baird). Length 6, height 5, diameter 2 mm. Off San Juan Island, Wash., in 25 fathoms.\*—Unalaska, Alaska, to Coronado Islands, Lower California.

*Psephidia ovalis* Dall, 1902. (Plate 42, fig. 4). Shell small, white, polished, oval, subcompressed; surface with obsolete concentric threads near the anterior base, but over most of the disk smooth; beaks small and very low, at about the anterior third of the length; lunule elongated, extremely narrow, nearly as long as the anterior dorsal slope; escutcheon linear or none; interior white, the pallial sinus moderate, pointed; internal margin delicately striated; hinge well developed, like that of *P. lordi*, with 3 entire cardinals and no anterior lateral tooth. The species is viviparous; some of those taken having as many as 30 young shells in the anal chamber. It is always distinguishable from *Psephis tantilla* by its hinge and oval form, and from *P. lordi* by its oval outline, compressed valves, and thinner shell. Length, 8.5; height, 6.5; diameter, 3 mm. (Dall). Puget Sound.—Bering Sea to San Diego, Calif.

### Family PETRICOLIDAE

PETRICOLA Lamarck, 1801

Shell oval or elongated, thin, tumid, anterior side short; hinge with generally 3 teeth in each valve, the external often obsolete; pallial sinus deep. (Tryon S. S. Conch.)

*Petricola carditoides* Conrad, 1837. (Plate 42, figs. 6a, 6b). Shell of medium size and variable outline, generally oblong-ovate, convex, thick; surface ornamented with fine concentric, incremental lines, which sometimes form irregular ridges, and by fine wavy, radiating lines; hinge area prominent; 3 cardinal teeth in each valve, the anterior one smallest; margins smooth. (Conrad). Length 30, height 18, diameter 15 mm. San Juan Island, Wash.\*—Vancouver Island to Lower California.

### Family COOPERELLIDAE

COOPERELLA Carpenter, 1864. (Oedalina)

Shell small, thin, smooth, or concentrically striate or undulate, equivalve, nearly equilateral, with entire margins; ligament long; resilium short; hinge plate narrow, carrying 2 right and 3 left subumbonal, divaricating, short cardinal teeth; laterals none; pallial sinus narrow, with an ample sinus. (Arnold). Type *C. subdiaphana* Carpenter.

*Cooperella subdiaphana* Carpenter, 1864. (Pl. 13, fig. 1, Arnold's Palaeont. San Pedro). Shell small, subquadrangular, subequilateral, convex, very thin and fragile; posterior extremity evenly rounded; anterior extremity rounded near base; surface smooth except for incremental lines; beaks slightly raised, sharp, prominent; 2 narrow, tall, sharp bifid teeth in left valve, 3 in right; pallial sinus very large. (Arnold). Length 12, height 9, diameter 6 mm. Queen Charlotte Islands.—Queen Charlotte Islands to Gulf of California.

### Family TELLINIDAE

#### TELLINA (Linne) Lamarck, 1799

Shell slightly inequivalve, compressed, rounded in front, angular and slightly folded posteriorly, umbones subcentral; teeth 2-2, laterals 1-1, most distinct in right valve; pallial sinus very wide and deep; ligament external, prominent. (Tryon S. S. Conch.) Type *T. virgata* Linne.

*Tellina* (Moerella) *salmonca* Carpenter, 1864. (Plate 41, figs. 3a, 3b). Shell small, suboval, convex, equivalve, inequilateral, thin; umbones anterior to the center, small, sharp; anterior extremely short, rounded, posterior dorsal margin straight; posterior extremely acutely rounded; ventral margin evenly arcuate; surface glossy, ornamented with fine, concentric incremental lines, and obsolete radiating scratches; cardinal tooth small, bifid; no lateral teeth; pallial sinus long, broad; one faint, internal, submarginal, posterior, radiating ridge. (Arnold). Length 11, height 8, diameter 4 mm. Off San Juan Islands, Wash., in 30 fathoms; Nanaimo, B. C.; rare.\*—Aleutian Islands to San Pedro, Calif.

*Tellina* (Angulus) *modesta* Carpenter, 1864. Shell small, white, rather short with a thick but obscurely defined ray behind the anterior adductor scar. Length, 16; height, 11; diameter, 4 mm. (Dall). Victoria and Comox, B. C., by Rev. G. W. Taylor.\*—Vancouver Island to San Francisco, Calif.

*Tellina* (Angulus) *carpenteri* Dall, 1900. (Plate 10, fig. 4; plate 41, figs. 10a, 10b). Shell small, thin, shining, rose color or white. The elevated internal ray is absent or obsolete. Length, 10; height, 6; diameter, 2 mm. (Dall). Quatsino Sound, and near Victoria, B. C.—Forrester Island, Alaska, to Gulf of California.

*Tellina* (Oudardia) *buttoni* Dall, 1900. (Plate 41, figs. 7a, 7b). Shell elongated, subequilateral, compressed, polished, white, rounded before, slightly shorter and pointed behind, with a slight flexuosity;

surface finely concentrically grooved, with wider interspaces, the sculpture stronger on the right valve and anteriorly; beaks low, inconspicuous; interior polished, white, with a well-marked thickened ray behind the anterior adductor scar; pallial sinus reaching the ray, confluent below. Length, 16; height, 9.5; diameter, 3.5 mm. (Dall). Off San Juan Island, Wash.; Departure Bay, Vancouver Island.\*—Lituya Bay, Alaska, to Gulf of California.

*Tellina* (Peronidia) *bodegensis* Hinds, 1844. (Plate 41, fig. 5). Shell of medium size, elongated, narrow-ovate, rather thick; umbones posterior to center and pointing posteriorly; anterior portion of shell evenly rounded, the dorsal and ventral lines being nearly parallel; posterior dorsal margin depressed back of umbo, running off quite obliquely to a line which truncates the posterior end near the base; basal posterior angle nearly a right angle; basal line nearly straight; a prominent bifid cardinal tooth on each valve; pallial sinus long and narrow; generally thickened anteriorly. (Arnold). Length 48, height 25, diameter 12 mm. Queen Charlotte Islands.—Queen Charlotte Islands to Gulf of California; Japan?

MACOMA Leach, 1819

Shell without lateral teeth, usually subtrigonal and with a marked posterior flexure, the surface feebly sculptured concentrically or smooth; the siphons naked. (Dall). Type *M. tenera* Leach.

*Macoma incongrua* Martens, 1865. (Plate 10, fig. 5). Shell white, thin, inflated, rather rounded oval, concentrically irregularly striated, covered with a thin, pale epidermis; posterior side subacuminated, sloping above, sloping upward beneath, obtuse at the end, angle obscure, flexure inconspicuous, anterior side rounded; umbones round, very slightly leaning backward; hinge margin with cardinal teeth small, no lateral teeth. (Conch. Iconica). The above is Sowerby's description of *T. rotundata* which is a synonym for this species. Length 36, height 31, diameter 15 mm. Off San Juan Island, Wash.\*—Arctic Ocean to San Diego, Calif.; Japan.

*Macoma brota* Dall, 1916. (Pl. 44, fig. 11, Beechey's Voyage to the Pacific and Behring's Straits; Mollusca). Shell subovate, dull white, striated; posterior side strongly flexuous with obscure radiating angle, postangular area convex, with dorsal margin sloping and subtruncated, sinuous; anterior side somewhat inflated, rather longer, dorsal margin obliquely convex, umbones sloping backward, ligament partly imbedded, hinge margin with small central and no

lateral teeth. Length, 64; height, 50; diameter, 18 mm. (Dall). Off Matia Island, Wash., in 30-35 fathoms.\*—Arctic Ocean to Puget Sound.

*Macoma brota lipara* Dall, 1916. (Plate 10, fig. 1). Shell resembling *M. brota* but more rotund, less rostrate, with a wider and rounder anterior end, shorter and more rounded posterior end, and more polished surface. Length, 74; height, 57; diameter, 25 mm. (Dall). Puget Sound.—Arctic Ocean to Puget Sound.

*Macoma calcarea* Gmelin, 1792. (Plate 10, fig. 2). Shell of medium size, suboval, slightly convex, inequilateral, thin; anterior end shorter than posterior, with a fold running from apex to lower anterior extremity, which is biangular; anterior dorsal margin straight; anterior end evenly rounded; beaks anterior to the middle, small, inconspicuous; surface sculptured by fine incremental lines; two cardinal teeth on left valve, anterior one bifid; pallial sinus large. Length, 64; height, 44; diameter, 15 mm. (Arnold). Off Matia Island, Wash., in 35 fathoms.\*—Arctic Ocean to Monterey, Calif.; northern Japan.

*Macoma nasuta* Conrad, 1837. (Plate 32, figs. 1a, 1d). Shell ovate, compressed, smooth but not polished; anterior side dilated, posterior side cuneiform, extremely truncated, much above the line at the base; fold carinated on the superior valve; beaks central, slightly prominent; epidermis extremely thin and deciduous, finely wrinkled, brown; pallial impression of the left valve joining the anterior cicatrix at its lowest posterior angle. (Conrad). Length 76, height 54, diameter 23 mm. San Juan Island, Wash., general, on shore.\*—Kodiak Island and Cook Inlet, Alaska, to Scammon's Lagoon, Lower, California.

*Macoma kelseyi* Dall, 1900. (Pl. 49, fig. 7, Trans. Wagner Free Inst. Sci., Philadelphia, vol. 3). Shell large, solid, heavy, compressed, slightly flexed; beaks subcentral, prominent, pointed, anterior end evenly rounded into an arcuate base and dorsal margin; posterior end lanceolate, the dorsal margin nearly rectilinear; surface sculptured only by strong, rather irregular lines of growth; hinge-plate short, broad, strong; teeth normal, elongated, large; pallial sinus discrepant in two valves; left valve with the upper part of the sinus sinuous, extending from the posterior to the anterior adductor, behind which is a thickened obscure ray; right valve with the sinus short, gibbous, the anterior end rounded, thence the line curves backward before coalescing with the pallial line below. It was described

from a Pleistocene shell from San Diego, Calif. Length, 86; height, 56; diameter, 20 mm. (Dall). Known alive only from off Brown Island, Wash., in 3-4 fathoms.\*

*Macoma inquinata* Deshayes, 1854. (Plate 32, figs. 2a, 2b, 3a, 3b). Shell of medium size, suboval, convex, thin, equivalve; umbones sub-central; anterior end dilated rather prominently so in front of umbo of right valve; posterior end evenly arcuate from umbo and acutely rounded at posterior end about half way between dorsal and ventral margins; ligament of medium length, not prominent; two small cardinal teeth in each valve; pallial sinus does not reach anterior muscle-impression in left valve. (Arnold). Length 38, height 28, diameter 17 mm. San Juan Island, Wash.\*—Bering Strait to Monterey, Calif.; Japan.

*Macoma inquinata arnheimi* Dall, 1916. (Plate 10, fig. 3). Shell resembling the typical *M. inquinata* but shorter and relatively more plump; the beaks 15 mm. behind the anterior end; the basal margin obliquely twisted. Length, 39; height, 30; diameter, 14 mm. (Dall). San Juan Island, Wash.\*—Kodiak Island, Alaska, to San Francisco, Calif.

*Macoma balthica* Linne, 1758. (Plate 41, figs. 1, 2, 9). Shell rather round, thick, somewhat ventricose, pale-rose or white, with a thin epidermis, equivalve; dorsal margin arched sloping; ventral margin slightly contracted; anterior side rounded; dorsal margin slightly excavated near the umbones. (Conch. Iconica). Length 27, height 22, diameter 11 mm. San Juan and Orcas Islands, Wash.—Point Barrow, Alaska, to San Diego, Calif.; northern Japan.

*Macoma inflatula* Dall, 1897. (Plate 4, fig. 6). Shell small, thin, inflated; full and rounded in front; shorter, compressed and pointed behind, the rostrum strongly bent to the right; surface smooth except for lines of growth, often polished cream color or whitish, sometimes pale brown with darker umbones, covered with a papery, dehiscent epidermis, which is either gray or greenish; ligament short; interior whitish, the pallial sinus reaching before the vertical of the beaks, rounded, subequal in the two valves; left with a strong slightly bifid anterior, and a simple smaller posterior cardinal tooth; right valve with two nearly equal grooved cardinals. Length, 24; height, 17; diameter, 8.8 mm. (Dall). Off San Juan Island, Wash., in 25 fathoms; Departure Bay, B. C.\*—Arctic Ocean to Ballenas Lagoon, Lower California.

*Macoma yoldiformis* Carpenter, 1864. (Plate 41, fig. 6). Shell

small, subelliptical, compressed, very thin and fragile; umbones slightly posterior to center; anterior end evenly rounded, longer than posterior side, which is very faintly folded, biangular and more cuneiform; surface smooth, except for very fine incremental lines; ligamental area scooped out about half length of posterior end, teeth very small. Length, 24; height, 23; diameter, 6 mm. (Arnold). Off San Juan Island, Wash., in 20-25 fathoms.\*—Straits of Fuca to San Diego, Calif.

*Macoma alaskana* Dall, 1900. (Plate 4, fig. 5). Shell small, very inequilateral, moderately inflated, white, with a polished pale-greenish periostracum; beaks low but acute, two-fifths of the whole length of the shell from the posterior end; anterior end produced, evenly rounded, posterior end descending rapidly to a rather blunt point; surface sculptured only with faint incremental lines; hinge normal, strong for the size of the shell; pallial sinus discrepant, in the right valve small, gibbous, short, about two-thirds confluent below; in the left valve large, reaching nearly to the anterior adductor scar, and three-fourths confluent below. Length, 14; height, 9; diameter, 4 mm. (Dall). Ione Inlet, B. C., by Dr. C. M. Fraser.\*—Alaska; Vancouver Island.

*Macoma quadrana* Dall, 1916. Shell small, white, polished, intermediate between *M. carlottensis* Whiteaves, and *M. inflatula* Dall, but smaller than either; periostracum pale straw color, slightly iridescent, microscopically concentrically striated; anterior end larger, posterior end short, obliquely subtruncate, the rostrum slightly bent to the right; the right valve a little flatter than the left; two faint low riblets extending from the beaks to the posterior basal angle; hinge very weak, pallial sinus deep and high. Length, 19; height, 13.5; diameter, 7 mm. (Dall). Nanoose and Departure Bays, B. C., by Dr. C. M. Fraser.\*—Boca de Quadra, Alaska to Acapulco, Mex.

*Macoma indentata* Carpenter, 1864. (Plate 41, fig. 4). Shell of medium size, rather narrow, suboval, compressed, thin; umbones slightly posterior to the center; anterior end long and evenly rounded; posterior dorsal line straight; ventral line near posterior end indented, the posterior extremity being much projected and sharply rounded; fold prominent; ligamental area short, scooped out. (Arnold). Length 50, height 32, diameter 14 mm. Puget Sound.—Puget Sound to Lower California.

*Macoma secta* Conrad, 1837. (Plate 41, fig. 8). Shell triangular or subelliptical, equilateral, compressed, thin, smooth and polished, covered with a very thin shining yellowish epidermis; umbonal slope



angulated; posterior extremity broadly and obliquely truncated; cartilage short, thick, inserted on an elongated oblique riblike callus; margin beneath the cartilage with an ovate gape, appearing as if cut or broken; color white within and without. (Conrad). Length 80, height 64, diameter 28 mm. False Bay, San Juan Island, Wash.\*—Vancouver Island to Gulf of California.

### Family SEMELIDAE

SEMELE Schumacher, 1817

Shell rounded, subequilateral, beaks turned forward; posterior side slightly folded; hinge-teeth 2-2, laterals elongated, distinct in the right valve; external ligament short, cartilage internal, long, oblique; pallial sinus deep, rounded. (Tryon S. S. Conch.)

*Semele rubropicta* Dall 1871. (Plate 22, fig. 10). Shell usually pure white and brilliantly polished within, but occasionally with a faint yellowish or pinkish flush when very deeply colored externally. Inner margin, except on the hinge-line, always pure white. Outside covered with a thin yellowish green or olive epidermis, usually wanting, color yellowish white, with rose-pink and pure white rays, color stronger on the lines of growth. Sculpture consisting of incised lines radiating from the umbones where they become obsolete; crossed by rounded, smooth, concentric ridges rather sharply defined by concentric grooves. These ridges are usually regular but sometimes bifurcating. In perfect specimens the radiating lines and grooves are so sharp that their intersections appear as if punctured. Ligament pit deep and excavated, cardinal and lateral teeth moderate. Anterior end much produced, rounded, margin rounded below, posterior end very short, almost truncated; shell rather inflated. Lunule deeply impressed, narrow, lanceolate, short. General form subquadrate. Umbones inconspicuous, usually tinged with yellow. Hinge-line below the lunule with a purple spot. Interior marked with extremely faint radiating lines. Posterior portion of the inferior margin produced. Shell thick and solid. Length, 1.35 in.; height, 1.55 in.; diameter, .7 inches. (Dall). Off San Juan and Lopez Islands, Wash.; near Departure Bay, B. C.\*—Kamchatka Peninsula to San Diego, Calif.; Japan.

### Family PSAMMOBIIDAE

PSAMMOBIA Lamarck, 1818

Shell elongated, more or less pointed behind, compressed, somewhat rudely concentrically sculptured diversely from the disc; the

pallial sinus elongated and for most part coalescent below with the pallial line. (Arnold). Type *P. feroensis* Gmelin.

*Psammobia* (Gobreaus) *californica* Conrad, 1848. (Plate 46, fig. 3). Shell of medium size, elongated, nearly equilateral; beaks very minute, a little posterior to the middle; anterior end subtruncate above and produced and rounded below; posterior end evenly rounded. Surface smooth except for lines of growth. Conrad named and figured the species, but did not publish a description. Length 75, height 45, diameter 27 mm. Off San Juan Island, Wash., in 25-35 fathoms.\*—Aleutian Islands to San Diego, Calif.; Japan; Kamtchatka.

### Family SOLENIDAE

SOLEN (Linne) Scopoli, 1777

Shell very long, subcylindrical, straight, margins parallel, ends gaping; beaks terminal or subcentral; hinge-teeth one in each valve; ligament long, external; anterior muscular impression elongated; posterior oblong; pallial line extending beyond the adductors; sinus short and square. (Tryon S. S. Conch.)

*Solen sicarius* Gould, 1850. (Plate 34, fig. 1). Shell elongated, transversely oblong, subcylindrical or tubular, somewhat falcate; beaks terminal; anterior extremity truncate obliquely at an angle of about 30°, somewhat everted, the portion posterior to a line across from the beak to the base, concave; posterior extremity rounded; dorsal edge rectilinear; ventral edge regularly arcuate, so that the posterior extremity becomes about two-thirds the height of the anterior; surface notably undulated by the stages of growth, parallel to the posterior end; the dorsal and ventral triangles not definitely marked, covered by a firm, glistening, horn-coloured epidermis; valves very convex. Hinge with a single, erect, recurved, triangular tooth in each valve. (Gould). Length 3½ inches; breadth 7/20 of an inch; height 9/10 of an inch. Off entrance to East Sound, Wash.\*—Vancouver Island to San Quentin, Lower California.

*Siliqua* Megerle, 1811

Shell smooth, oblong; epidermis polished; an umbonal rib extending across the interior of the valve; pallial sinus short.

*Siliqua patula* Dixon, 1788. (Fig. 2, Dixon's Voyage Around the World . . . ). "Tis a thin shell, smooth within and without: one valve is furnished with 2 front and 2 lateral teeth; the other has one front and one side tooth, which slips between the others in the opposite valve: from the teeth, in each valve, proceeds a strong rib, which ex-

tends to about half-way across the shell, and gradually loses itself toward the edge, which is smooth and sharp. The color of the outside is white, circularly, but faintly, zoned with violet, and is covered with a smooth yellowish-brown epidermis, which appears darkest where the zones are: the inside is white, slightly zoned, and tinted with violet and pink. The animal, as in all species of this genus, protrudes beyond the ends of the shell very much, and is exceedingly good food. (Dixon). The above is the original description as given in Dixon's Voyage, page 355, with the figure on the page opposite. Length about 150 mm. West of Rose Spit, Queen Charlotte Islands; a small specimen, by Rev. G. W. Taylor.—Alaska to Vancouver Island (?); Okhotsk Sea.

*Siliqua patula nuttallii* Conrad, 1837. (Plate 34, figs 2a, 2b). Shell oblong-oval, thin, fragile, compressed; posterior margin more obtusely rounded than the anterior; colour white, obscurely rayed; epidermis horn colour, with paler spots; beaks purple; cardinal teeth 2 in the right valve, lamellar, remote; in the left valve 4; rib broad, oblique. Length, four and a half inches. (Conrad). Puget Sound, southern part.—Lituya Bay, Alaska, to Monterey, Calif.

### Family MACTRIDAE

MACTRA Linne, 1758

Shell nearly equilateral; anterior hinge-tooth A-shaped, with sometimes a small laminar tooth close to it; lateral tooth double in the right valve; ligament set off by a shelly lamina rising between chondrophore and ligament; cardinals generally coalescent above; laterals smooth or finely granular. (Arnold). Type *M. stultorum* Linne.

*Mactra* (*Mactrotoma*) *californica* Conrad, 1867. (Pl. 18, fig. 12, Journ. Acad. Nat. Sci. Philadelphia, vol. 7). Shell of medium size, subtrigonal, subequilateral, compressed, thick; umbones subcentral, turned anteriorly, margins only slightly arcuate; posterior side with a narrow, submarginal fold; posterior extremity quite sharply rounded; anterior dorsal line slightly depressed in front of umbones; anterior extremity evenly rounded; ventral margin evenly arcuate; surface sculptured with fine concentric lines; cartilage pit triangular, deep, separated from posterior ligamental groove by a ridge; cardinal teeth sharp, narrow, prominent; anterior ligament groove long, narrow, with prominent interior margin; pallial sinus rather deep, rounded, not coinciding with ventral lines. (Arnold). Length 38, height 26, diameter 14 mm. Neah Bay, Wash.—Neah Bay, Wash., to San Diego, Calif.

SPISULA Gray, 1838

*Mactrae* with a ligament sagittate, set in a callous area close to

the dorsal margin, and not set off from the chondrophore by any shelly ridge. (Arnold). Type *Mactra solida* (Linné) Gray.

*Spisula* (Hemimacra) *alaskana* Dall, 1894. (Plate 4, fig. 4). Shell large, thick, somewhat compressed; the anterior side a little shorter, and the hinge margin is slightly concave, posterior slope convex and broader, the extremity slightly gaping. Base curved with the posterior end a little broader, beaks somewhat elevated, and behind them there is an elevated line extending to the lower angle. Sculpture consists of irregular growth lines coarser toward the posterior end. Epidermis is coarse and wrinkled; the surface of the shell has a rugged appearance from the coarse growth lines, and rendered more rugged by the folds of the thick epidermis. Interior bluish-white. Hinge supports strong and smoothly rounded, V-shaped; tooth strong, with the anterior side in right valve more elevated than the posterior; lateral teeth short and slender. Muscular impressions large, and pallial sinus deep and wide. Length 135, height 90, diameter 50 mm. Griffin Bay, San Juan Island, Wash., in 30-35 fathoms.\*—Arctic Ocean to Puget Sound and northern Japan.

*Spisula* (Hemimacra) *voyi* Gabb, 1869. (Plate 38, figs. 1, 2), Shell broad, inequilateral; beaks straight and sloping; anterior end very much produced, rounded and narrow; posterior end obliquely truncated; base broadly and regularly rounded. Surface marked by numerous irregular and rather strong lines of growth. (Gabb). Length 150 mm. Puget Sound.\*—Alaska to Puget Sound.

I think we have the 2 preceding species in Puget Sound, at least the hinge teeth are not alike. In *S. alaskana* the beaks are posterior to the center of shell; cardinal tooth of left valve extends partially over the chondrophore; the anterior lateral tooth is elongated, thin, and near the beaks is nearly divided so as to come near forming an additional cardinal tooth. So far the true *S. alaskana* has not been reported as fossil, but it has been confused with *S. voyi* Gabb. In *S. voyi* the beaks are anterior to the center. This was described from a fossil from near Humbolt Bay, Calif. One recent specimen was found in Puget Sound. Further study of many specimens may show that we have 3 species of this type, but for the present we feel sure of 2.

*Spisula catilliformis* Conrad, 1867. (Plate 39, fig. 1). Shell suboval, inequilateral; anterior side slightly flattened or contracted; posterior side with an oblique shallow groove or fold; lines of growth coarse and prominent; lunule very long, elliptical; ventral margin tumid posteriorly; cardinal pit oblique, large; pallial sinus extending

beyond the middle of the valve. Length, 4 inches; height, 3  $\frac{7}{8}$  inches. (Conrad). Neah Bay, Wash.—Neah Bay, Wash., to San Diego, Calif.

*Spisula falcata* Gould, 1850. (Plate 17, figs. 1-3). Shell large, solid, transversely ovate-triangular, subfalcate, inequilateral, hinder end short, moderately gaping, white covered with a thick, shining, dusky, straw-colored epidermis; surface delicately marked by incremental lines, with obscure distant radiating ridges; beaks acute, nearly touching, post median, rather compressed; anterior end narrower than posterior, triangular, somewhat ascendant, extremity rather acute; posterior end broadly rounded, truncate at tip, in young specimens more triangular; basal edge regularly arcuate; anterior dorsal edge rectilinear, presenting a plane lanceolate space in front of the beaks; posterior dorsal edge rounded, with a coarse, loose, dusky epidermis. Valves slightly convex, within milk-white; siphonal sinus reaching as far as beaks. Cardinal area large; ligamentary pit large, oblique, shallow; sides of V-tooth very unequal, strong; lateral teeth thin, elevated, anterior one of left valve bilobate. (Gould). Length 68, height 49, diameter 20 mm. Puget Sound.—Puget Sound to Cortez Bank and the Coronado Islands, Mex.

*Spisula* (Symmorphomactra) *planulata* Conrad, 1837. (Plate 17, figs. 4-6). Shell triangular, much compressed, subequilateral; the posterior side rather shorter than the anterior; anterior side subcuneiform; posterior side with an obscure submarginal line, extremity rounded; beaks elevated; epidermis smooth, shining. (Conrad). Length 43.8 mm. Departure Bay, Vancouver Island, B. C., by Rev. G. W. Taylor.\*—Vancouver Island to Cape San Lucas, Lower California.

#### SCHIZOTHAERUS Conrad, 1853

Shell large, inequilateral, thin, inflated; siphonal gape very large, pedal gape narrow; ligament minutely sagittate, separated by a shell lamina from the pit, which lamina is often recurved and patulous; left cardinal high, compressed; laterals small but distinct in both valves; right cardinal feeble. (Conrad). Type *S. nuttallii* Conrad.

*Schizothaerus nuttallii* Conrad, 1837. (Plate 33, figs. 1a, 1b). Shell elliptical, slightly gibbous from beak to base; posterior side produced; ligament margin slightly declining, rectilinear, extremely obliquely subtruncated; umbo prominent; color white; epidermis very thin, brown, wrinkled on the margin. (Conrad). Length 150, height about 100 mm. Olga, Wash.; low tide.\*—Wrangell, Alaska, to San Diego, Calif.

*Schisothaerus nuttallii capax* Gould, 1850. (Pl. 1, fig. 4, Conch. Iconica, as *Mactra*). "Testa magnifica, ventricosa, ovato-rotundata, antice rotundata, postice subtriangularis, truncata, valde hians, concentric undulato-striata, epidermide luteo-virdi (post costam medianum radatim corrugato) induta; umbonibus tumidis, incubentibus, attigentibus: cardo validus; fovea lata, ablique triangulari; dente cardinali crasso, erecto, plicato, basi appendiculato; dentibus lateralibus compressis, conspicuis. Interior calcarea; sinu siphonali linguiformi, dimidam longitudinis testae attigente." No other species approaches this in size and capacity. Long.  $5\frac{3}{4}$ , alt. 4, lat. 3 poll. Hab. Puget Sound. (Gould). The above is the original description.

Shell very largely inflated, ovately subrhomboidal, inequilateral, transversely striated and rough, whitish, covered toward the margin with a black-brown epidermis, anterior narrowly gaping, posteriorly very broadly gaping; umbones large, obtuse, approximated; sinus of the mantle broad, deep, horizontal. (Conch. Iconica). This is the description given by Middendorff but he called the species *Lutrarina maxima*, and gave the habitat as California. Length 183, height 165, diameter 125 mm. This is the largest specimen recorded. Departure Bay, Vancouver Island, by Rev. G. W. Taylor.—Kodiak Island, Alaska, to San Francisco, Calif.

### Family MYACIDAE

*Mya* (Linne) Lamarck, 1799

Shell oblong, ventricose, irregularly wrinkled, posteriorly broadly gaping; anterior side much inflated, obliquely tumid, dorsal margin elevated; umbones angular, prominent, leaning backwards; posterior side narrow; dorsal margin depressed; terminal margin truncated. (Tryon S. S. Conch.)

*Mya truncata* Linne, 1758. (Plate 6, fig. 4). Shell oblong, ventricose, irregularly wrinkled, posteriorly broadly gaping; anterior side much inflated, obliquely tumid; dorsal margin elevated; umbones angular, prominent, leaning backwards, posterior side narrow; dorsal margin depressed; terminal margin truncated. Length 50, height 30, diameter 20 mm. Off O'Neal Island and Entrance to East Sound, Wash., in 25-35 fathoms.\*—Arctic Ocean to Puget Sound; Circumboreal.

*Mya intermedia* Dall, 1898. (Plate 3, fig. 11). This species is intermediate in character between *M. arcuaria* and *M. truncata*, there are constant though not conspicuous differences in the hinge. This

shell grows to a very large size on the Alaskan Peninsular and is very puzzling. Length, 6 inches. (Dall). Off San Juan Island, Wash.; young specimens only, the largest we found was not much over 25 mm.\*—Point Barrow, Alaska, to Monterey Bay, Calif.

*Mya arenaria* Linne, 1758. (Plate 47, fig. 4). Shell ovate, solid, brown, concentrically lightly wrinkled, gap strongly on each side; anterior side ventricose, broad; posterior side cuneate, subdepressed, slightly angular, rather obliquely truncated at the end; ligament-bearing plate in left valve large, produced pallial impression broadly and squarely sinuated. (Conch. Iconica). Length 67, height 37, diameter 18 mm. Introduced with "Seed" oysters from the Atlantic. Along shore, on most of the islands of San Juan County, Wash.\*—Victoria, B. C., to Monterey Bay, Calif.

#### CRYPTOMYA Conrad, 1349

Shell inequilateral, transverse, oblong, gaping behind; valves with radiating, sometimes crossed by concentric striae; right valve with a lamellar tooth, left valve with a broad fosset; ligament internal; pallial impression with a small sinus. (Conrad).

*Cryptomya californica* Conrad, 1837. (Plate 45, figs. 6, 9). Shell suboval, convex-depressed, with radiating striae; obscure, except toward the posterior extremity, where they are distinct; posterior margin obliquely truncated, rectilinear; beaks central, ligament margin arcuate; tooth much dilated, oblique; colour white; pallial impression without a sinus, but forming a right angle posteriorly. (Conrad). Length 31, height 25, diameter 11 mm. San Juan Island, Wash.\*—Chichagoff Island, Alaska, to Topolobampo, Mex.

#### SPHENIA Turton, 1822

Shell oblong; right valve with a curved, conic tooth in front of the oblique, subtrigonal cartilage-pit. (Tryon S. S. Conch). Type *S. binghami* Turton.

*Sphenia fragilis* Carpenter, 1857. Shell somewhat elongate, inequilateral, opaque, but not solid, inequivalve; the left valve being smaller and somewhat flatter; the epidermis is of a dull yellow, closely attached, beneath which the surface is almost smooth, or may be wrinkled with concentric and rather distant wrinkles of growth. The ventral margin more or less straight, and usually ascends a little behind. The right umbo projects somewhat above the dorsal line; beaks acute and incurved. There is an umbonal ridge in each valve. Interior white. Hinge with an erect tooth in left valve and a corres-

ponding tooth-recptacle in the right valve. Living in the burrows of worms and mollusks, and among kelp holdfasts. Length 11, height 9 mm. Victoria, B. C., by Dr. J. Newcombe.—Vancouver Island to Mazatlan, Mex.

### Family SAXICAVIDAE

PANOPE Menard, 1807

Shell equivalve, thick, oblong, gaping at each end; ligament external, on prominent ridges; one prominent tooth in each valve; pallial sinus deep. (Arnold).

*Panope generosa* Gould, 1850. (Plate 16, figs. 1, 2). Shell large and ponderous, chalky white, of a somewhat quadrilateral form, the basal and hinge margins being nearly parallel; the posterior extremity broadly truncated a very little obliquely, and the anterior extremity broadly rounded; anteriorly it gapes slightly, but posteriorly it gapes broadly, and the valves are here somewhat everted. The surface is coarsely undulated concentrically, and covered by an obliquely and somewhat plumosely wrinkled dirty yellow epidermis. The beaks are sharp and prominent, placed near the middle of the superior margin; the anterior umbonal slope is tumid, the posterior a little compressed. The hinge is rather slender, having a single elevated, erect, obliquely triangular tooth in each valve, with a pit behind that in the right valve, and a crest-like elevation for the ligament behind them. Ligament external and double. Cavity of the beaks profound; muscular and pallial cicatrices broad and well impressed; posterior muscular scar but little broader than the pallial impression; siphonal sinus shallow, small. (Gould). Length 150, height 75, diameter 100 mm. Off entrance East Sound, Wash., dead; Victoria and Comox, B. C., by Dr. C. F. Newcombe.\*—Vancouver Island to San Diego, Calif.

*Panope generosa solida* Dall, 1892. Shell heavy, somewhat arcuate, the pedal region slightly obliquely truncated, and nymph strong, and the ligamentary attachment twice as long as in the typical form, the pallial sinus deeper. Length, 177; height, 97; diameter, 62 mm. (Dall). Puget Sound.—Puget Sound to San Francisco Bay, Calif.

PANOMYA (Gray) Adams, 1858

Shell solid, large, irregular, with a single cardinal tooth under the beak in each valve; the pallial line of unconnected rounded impressions. (Arnold). Type *P. (Mya) norvegica* Spengler.

*Panomya ampla* Dall, 1898. (Plate 6, fig. 3). The shell is chalky white with a black dehiscent tarry periostracum, which is



rarely preserved even in the living animal, which the valves only partly cover. (Dall). Shell large, irregularly subquadrate, ventricose, thick; beaks subcentral, incurved, small, sharp, elevated; anterior extremity rounded, projected farthest above middle; posterior extremity gaping, abruptly and irregularly truncated, with angular corners above and below; basal margin nearly rectilinear; 2 large folds separate the shell into three parts; one fold extends to the lower posterior angle from the umbo; and the other extends to the lower anterior angle from the umbo; surface roughly sculptured by concentric lines and undulations, one small cardinal tooth in each valve; cartilage-process rather short, projecting; pallial line of unconnecting, rounded impressions. (Arnold). Length 60, height 46, diameter 26 mm. Off entrance to East Sound and off O'Neal Island, Wash.\*—Arctic Ocean north of Bering Strait, to Puget Sound.

#### SAXICAVA Fleuriau, 1802

Shell when young symmetrical, with 2 minute teeth in each valve; adult rugose, toothless; oblong equivalve, gaping, ligament external; pallial line sinuated, not continuous. (Tryon S. S. Conch.) Type *S. rugosa* Lam.

*Saxicava arctica* Linné, 1767. (Plate 40, fig. 4). Shell oblong, rugose, thick; posteriorly spiniferous when young, with 2 teeth on the hinge; without teeth on the hinge when adult; anterior side narrow, short; ventral margin sinuous; umbones depressed, anterior; posterior side broader, square, biangular, broadly truncated. (Conch. Iconica). Length, 25; height 13; diameter, 12 mm. Off San Juan Island, Wash.\*—Arctic Ocean to Panama; Atlantic.

*Saxicava pholadis* Linné, 1771. (Plate 40, fig. 5). Shell uniform, generally oblong, rounded before and truncate behind, with a prominent ridge from the beaks to the lower posterior angle; surface rough. (Gould Invert. Mass.) Length, 40; height, 20; diameter, 13 mm. Burrard Inlet, B. C.\*—Arctic Ocean to Panama; Atlantic.

#### Family PHOLADIDAE

##### ZIRFAEA (Leach) Gray, 1847

Shell oval, cardinal margin scarcely reflected; no accessory valves, the beaks protected by a membrane; usually a thin, fugacious epidermis; anteriorly greatly gaping. (Tryon S. S. Conch.) Type *Z. crispata* Linne.

*Zirfaea gabbi* Tryon, 1863. (Pl. 1, fig. 1, Proc. Acad. Nat. Sci. Philadelphia, 1863). Shell large, transverse, obliquely divided by a

deep furrow proceeding from the umbonal apex to the basal margin and forming a corresponding rib on the internal surface of the valve. Posteriorly to the furrow the shell is marked only by growth lines which, in crossing it, are elevated into sharp ribs, in which character they are continued to the anterior margin. The portion of the shell anterior to the radiating furrow is ornamented with numerous longitudinal ribs, approximating in pairs and rendered acutely scabrous at the intersection of the rib-like growth lines. Ventral anterior margin emarginate. Dorsal anterior margin reflected and closely appressed over the beaks. Posterior dorsal margin declining somewhat to the quadrately rounded posterior lateral end. Color white. (Tryon). This species is closely allied to *Z. crispata*, and was so called by the collectors, for a time. Length 72, height 35, diameter 30 mm. Lisa-beula, Vashon Island, Wash., by C. C. Engberg.—Bering Sea to San Diego, Calif.

#### PHOLADIDEA Turton, 1819

Shell globose-oblong, with a transverse furrow; anterior gape large, closed in the adult by a callous plate; two minute accessory valves in front of the beaks. Type *P. papyracea* Solr.

*Pholadidea penita* (Conrad) 1837. (Plate 40, figs. 3a, 3b). Shell ovate, elongated, contracted submedially and grooved; anterior side inflated, with decussating lines, the radiating striae having a granulated appearance, posterior side subcuneiform, extremity truncated, with a membranous expansion or appendage; apophysis oblique, slender, spoon-shaped at the extremity. (Conrad). Length 70, height 40, diameter 35 mm. East side Mudge Island at False Narrows, B. C., by Dr. C. M. Fraser.\*—Chirikoff Islands, Alaska, to San Pedro, Calif.

*Pholadidea penita sagitta* Stearns, 1916. (Pl. 18, fig. 7, Journ. Acad. Nat. Sci. Philadelphia, vol. 7). Shell closely similar to *P. penita* Conrad, but with shorter proportions, measured longitudinally, and with a corresponding widening of the dorsal appendages of the adult. In all other respects it resembles *P. penita*, of which it is doubtless a variety. Length, 27; height, 16; diameter, 15 mm. (Dall). Puget Sound.—Puget Sound to Socorro Island, off Mex.

*Pholadidea ovoides* Gould, 1851. (Plate 40, figs. 1a, 1b, 2a, 2b). Shell oval, somewhat solid, ashy colored, posterior end gaping widely and with much produced epidermis; anterior ventral margin closed by a calcareous plate; beaks situated near the anterior third of the shell; valves divided by a median groove, anterior portion rounded, with concentric, radially striated layers, with a subcylindrical,

roughened posterior portion, with distinct striae; cardinal region tapering, dilated toward the apex, with no auxiliary valves. (Gould). Length 38, height 24, diameter 24 mm. False Narrows, B. C., by Dr. C. M. Fraser.\*—Bering Sea to Gulf of California.

*Pholadidea* (*Nettastomella*) *rostrata* Valenciennes, 1846. (*Nettastomella darwini*. (Plate 27, figs. 7, 10). Shell small, short, widely gaping anteriorly, sculpture radiately scabrous, divided by a consticted deep groove; behind the groove concentrically ridged; anterior portion with fine concentric ridges which continue around the aperture, curved up to the umbones, thus forming an inverted U-shaped opening. The valves at the posterior end are prolonged like a duck's bill. It differs from *Jouanettia* in having the valves equal, and from *Pholadidea* s. s. in that the ends are shelly and prolonged, instead of a corneaceous cup. A very delicate thin shell, of a pure white color. Found living in the shale with other species of *Pholads*. The original description could not be had. Length of adult specimen figured about 28 mm. Vancouver Island B. C.—Vancouver Island to San Diego, Calif.

#### XYLOPHAGA Turton, 1822

Shell globular, with a transverse furrow; gaping in front, closed behind; pedal processes short and curved; anterior margins reflected, covered by 2 small accessory valves; burrow oval, lined with shell. (Tryon S. S. Conch.) Bores 25 mm. deep, and across the grain, in floating wood and timbers which are always covered by the sea.

*Xylophaga mexicana* Dall, 1908. Shell small, short, posterior area rounded behind, concentrically marked only with incremental lines; median furrow wide, channelled, in the adult bounded behind by a flattened thread, in front the elevated margin of the channel is obliquely serrate by the terminations of the sagittate sculpture of the anterior area, which a little more anteriorly becomes very fine, so as to require strong magnification to bring out its character; anterior margin of the valves with a rectangular sulcus, from whose apex an impressed line proceeds to the umbo, the angulation of the sculpture resting on this line; anterior auriculation small; anterior dorsal margin strongly reflected; interior smooth except for a strong flattish rib which extends from the umbo under the middle of the wider external channel; umbo much incurved; myophore small and slender. Alt. 4.2; lon. 5.2; diam. about 4 mm. (Dall). Puget Sound.—Puget Sound to Acapulco, Mex.

*Xylophaga washingtona* Bartsch, 1921. In *Xylophaga washingtona* there are about 10 denticulated ridges to a millimeter in the

center of the posterior area, and the denticulated ridge bearing posterior median portion is 1.2 mm. in width at the angle of junction of the posterior with the median part. Length, 5.7; altitude, 5.5 mm.; the type specimen. Departure Bay, B. C.\*—Albatross Station 2867, off coast of Washington; San Juan Islands, Wash.; Departure Bay, B. C.

### Family TEREDIDAE

#### BANKIA Gray, 1842

Siphonal pallets elongated and penniform, the blade consisting of articulated pieces radiating obliquely from the style. (Tryon S. S. Conch.)

*Bankia setacea* Tryon, 1863. (Pl. 1, figs. 2, 3, Proc. Acad. Nat. Sci. Philadelphia, 1863). Shell large, of nearly equal length and breadth. Beaks high, narrow, incurved and thickened, the apex lower than the auricle, which is long, moderately wide, extending more than half the length of the valve and joining the medial portion by a rounded obtuse angle. Anterior area obliquely triangular, not more than half the length of the auricle, its upper edge projected by a rib culminating dorsally in a sort of knob. The anterior margin of the medial portion of the valve is straight, forming an acute angle with the triangular area; the posterior margin is oblique and somewhat convex. The junction of the auricle is marked externally by a depression of the surface, and internally by a projecting ledge. Apophysis short, oblique, broad. Base of valve tuberculate internally. The valve is white, tinged with pink anteriorly and slightly glossy. The anterior area, which is separated from the body whorl by a deep, narrow, sulcation, is sculptured by about 30 sharply cut, prominent, transverse ribs. The body is marked, first, by a narrow longitudinal area which is closely striate; then by a narrow double rounded rib, the surface of which is triangularly striate; then by a depressed space equally wide, with its sides accurately defined, and transversely sculptured. The whole surface of the body and auricle posteriorly is unmarked, except by growth lines, and the depression of the surface at the commencement of the latter. Pallet large; the jointed portion about the same length as the stalk, rather wide, with lateral extremities acuminate and inclining upwards. Sides of the joints fringed. These joints number about 16 or 18. Stalk very slender and rounded. Length and breadth of valves about  $\frac{1}{2}$  inch. Length of pallets  $1\frac{1}{4}$  inch. Breadth of upper portion of pallets about  $\frac{1}{6}$  inch. (Tryon). San Juan Island, Wash., in old logs.\*—Bering Sea to Gulf of California.

## CLASS SCAPHOPODA

## Family DENTALIIDAE

## DENTALIUM Linne, 1758

Shell tube-like, gradually tapering posteriorly, longitudinally ribbed, margin of the aperture sharpened; posterior end with an internal, slightly projecting tube, which is provided with a dorsiventrally elongated opening, the outer layer having a very slight emargination dorsally and ventrally. (Arnold). Type *D. elephantinum* Linne.

*Dentalium dalli* Pilsbry & Sharp, 1897. (Plate 5, fig. 14). Shell regularly but only slightly curved, evenly tapering, thin and fragile; opaque, slightly bluish-white. Surface brilliant, glossy and polished; but in all specimens seen, mainly dead or lusterless whitish from loss of the greater part of the superficial gloss, which remains near the aperture only, or sometimes in patches or irregular rings elsewhere. Growth-striae faint; no other sculpture. Aperture circular, not oblique. Apex rather large, with simple, circular, thin-edged orifice; no slit or notch. Length, 45; aperture, 4; at apex 1.5 mm. (Pilsbry & Sharp). Off Matia and Waldron Islands, Wash., in 25-30 fathoms.\*—Pribilof Islands, Bering Sea, to Aguja Point, Peru.

*Dentalium rectius* Carpenter, 1864. (Pl. 21, fig. 45, Tryon & Pilsbry's Manual Conch., vol. 17). Shell almost straight, slender and long, attenuated toward the apex, thin and fragile, bluish-white, somewhat translucent, with some opaque white flecks or rings, often encrusted near the aperture with a reddish deposit. Surface very glossy, polished, growth-marks being only faintly seen and sculpture absent. Aperture not oblique, almost circular, but the tube is a little compressed laterally; peristome thin. Apical orifice small, circular, without notch or slit, but from its extreme fragility the end is often nicked or broken. Length, 40; diameter at aperture 2.6; at apex 1 mm. (Tryon Manual Conch.) Off Matia and Waldron Islands, Wash., 25-30 fathoms.\*—Stephens Passage, Alaska, to Panama.

*Dentalium vallicolens* Raymond, 1904. Adult shell large, rather slender, moderately curved posteriorly, the latter half nearly straight; cream-white, often yellowish toward the mouth, shining where not eroded, earlier portion usually dull and chalky because of erosion; growth-lines fine, irregular, distinct, rarely an encircling groove due to repaired fracture; at the apex there are longitudinal, low, rounded, inconspicuous threads, of which 7 or 8 are more prominent and 3 to 6 in each interspace are less prominent; these die out, and fine, superficial striae appear, visible under the glass and continued to the mouth of the shell, 7 or 8 per millimeter of circumference; aperture

simple, circular, mouth slightly oblique. Young shell strongly curved, very slender for the first 8 or 10 millimeters of length, then rapidly enlarging; at first 7 or 8 angled, the angles defined by sharp ribs with channeled interspaces, then passing into the sculpture of the adult by successive interpolations of secondary riblets, while the primary ribs lose in prominence and the section of the shell becomes circular. Length, 64.5; diam. of aperture, 5.3 mm. (Raymond). Strait of Fuca.—Srait of Fuca to Gulf of California.

*Dentalium pretiosum* Sowerby, 1860. (*D. indianorum*). (Pl. 225, fig. 57, Sowerby's Thesaurus Conch.) Shell rather long, moderately curved and solid; opaque white, ivory-like, often with some faint dirty buff rings or tinted with that color at the smaller end. Sculpture of fine, irregular growth-striae and occasional deeper grooves caused by interrupted growth; usually with no longitudinal sculpture in adults, but sometimes showing longitudinal striae toward the apex, the young with numerous small riblets (but in southern specimens the longitudinal sculpture is more persistent). Aperture circular, oblique, the peristome thin. Apex rather broadly truncate, the orifice small, oblong, continued in a short notch on the convex side; often having a narrow raised rim. Length, 41; diameter, of aperture, 5; of apex, 2.7 mm. (Tryon Manual Conch.) Vancouver Island; in Rev. G. W. Taylor's Collection.\*—Forrester Island, Alaska, to Lower California.

#### CADULUS Philippi, 1844

Tubular, circular or oval in section; somewhat arcuate; varying from cask-shaped to acicular; more or less bulging or swollen near the middle or above, contracting toward the aperture. Surface smooth or delicately striated. (Tryon Manual Conch.) Type *Dentalium oculum* Phil.

*Cadulus hepburni* Dall, 1897. (Plate 44, fig. 6). Shell small, polished, smooth, white, nearly straight; apertures circular, their margins simple. Length of shell, 11; diameter at anterior end, 1.25; at posterior end, 0.75 mm. (Dall). Near Victoria, B. C., in 60 fathoms.—Victoria, B. C., to Monterey, Calif.

*Cadulus aberrans* Whiteaves, 1887. (Fig. 2, Trans. Ray. Soc. Canada, vol. 4, sec. 4). Shell slender, moderately but distinctly curved, large and much elongated for the genus, increasing very slowly but regularly in diameter, not distinctly (if at all) swollen in advance of the middle, and very slightly and scarcely perceptibly constricted immediately behind the aperture. Test extremely thin; surface polished,

very glossy and shining, smooth to the naked eye, but under a lens it is seen to be marked with minute and transverse but somewhat oblique lines of growth. (Whiteaves). Length, 13.5; breadth, 1.3 mm. Known only from Quatsino Sound, northwestern end of Vancouver Island.

*Cadulus tolmiei* Dall, 1897. (Plate 44, fig. 5). Shell small, thin, polished, translucent bluish white, rather arcuate and rapidly tapering behind; the anterior orifice oblique, nearly circular; the posterior orifice circular, simple; sculpture none, or only of obscure, incremental lines. Length, 12; maximum diameter, 2; minimum diameter, 0.7 mm. (Dall). Victoria, B. C.\*—Vancouver Island to San Quentin Bay, Lower Calif.

*Cadulus tolmiei newcombei* Pilsbry & Sharp, 1898. About the length of *C. tolmiei*, but decidedly more slender; greatest diameter contained nearly 6 times in length; section of the tube markedly oval. Length, 11; antero-posterior diameter at aperture, 1.45; at greatest bulging, 1.66; at apex, 0.66; lateral diameter at aperture, 1.55; at largest, 1.9; at apex, 0.75 mm. (Pilsbry & Sharp). Carter Bay, Winter Harbor, Vancouver Island, by Rev. G. W. Taylor.\*—Vancouver Island.

*Cadulus stearnsii* Pilsbry & Sharp, 1898 (*C. simplex* Pilsbry & Sharp). (Pl. 17, figs. 88, 89, Tryon & Pilsbry's Manual Conch., vol. 17). Shell short, decidedly curved, the bend mainly in the posterior half, very rapidly enlarging, tapering from the large aperture to the apex; thin, bluish-white, a little translucent, more or less flecked with opaque white (by incipient surface decay), or with eroded spots. Glossy, with close, fine distinct growth-striae, very obliquely passing around the tube, bending backward on the convex, forward on the concave side; in most specimens also showing faint, low traces of longitudinal cords on the convex side. Aperture somewhat wider than long, quite oblique, the periostome thin. Anal orifice circular, simple when perfect, but often with irregular, broken edge. Length, 8.6; diameter at aperture antero-posteriorly, 1.75; laterally, 1.9; diameter at apex, 0.7 mm. (Tryon Manual Conch.) B. C.—B. C. to San Quentin Bay, Lower California.

## CLASS GASTEROPODA

## Family ACTEONIDAE

ACTEON Montfort, 1810

Shell solid, ovate, with a conical, many-whorled spire, spirally grooved or punctate-striate; aperture long, narrow, rounded in front; outer lip sharp; columella with a strong, tortuous fold. Operculum horny, elliptical, lamellar. (Tryon S. S. Conch.) Type *A. tornatilis* Linne.

*Acteon* (Rictaxis) *punctocyclata* Carpenter, 1864. (Plate 1, fig. 9). Shell oblong with conoidal spire; white with two broad ashy or brown zones. Whorls 5, convex, separated by impressed and narrowly channelled sutures. Surface sculptured throughout with spiral equidistant conspicuously punctate grooves, the raised intervals smooth except for a fine engraved line along the middle of each. Grooves on the body whorl about 26. Aperture two-fifths to two-thirds the length of the shell; columella having a spiral fold above, obliquely truncated at base. Length, 13.5; diameter, 7 mm. (Tryon Manual Conch). Off Branden Island and in Nanoose Bay, B. C.; in 15-20 fathoms.\*—Vancouver Island to Magdalena Bay, Lower California.

## Family ACTEOCINIDAE

ACTEOCINA Gray, 1847. (*Tornatina* A. Adams).

Shell cylindrical, with a conic or flattened spire, the apex projecting and mamillar, sinistral, tilted at an angle with the body-whorl; suture channelled. Columella with one fold. (Tryon Manual Conch.) Gray did not give a description of his genus *Acteocina*, but did name a type, *Acteon wetherellii*. I have given the description of A. Adams for the genus *Tornatina*, as it is equal to Gray's *Acteocina*.

*Acteocina culcitella* Gould, 1852. (Plate 20, figs 5-7). Shell ovoid-cylindrical, rather solid, bluish white, covered by a rough straw colored epidermis; whorls five, the anterior one elongated, somewhat fusiform, rounded anteriorly, sculptured with fine, close-set revolving striae, more distinctly indicated when the epidermis is present; the 4 posterior whorls form a conical spire, having a suture so profound that they seem invaginated and quite detached from each other. Aperture linear, widening anteriorly, and in front somewhat trigonal. Inner lip formed by a sharp, very prominent, abruptly twisted white fold,



with a submarginal excavation, terminating acutely in front in such a manner as almost to form a canal. Length, 1 in.; breadth,  $\frac{1}{4}$  in. (Gould). Victoria and Departure Bay, B. C., by Rev. G. W. Taylor.—Kodiak Island, Alaska, to Puget Sound.

*Acteocina eximia* Baird, 1863. (Plate 5, fig. 15). Shell cylindrical, greenish-buff, striated, the striae minute, close, undulating; spire very short and concavely excavated. Aperture long, effuse at base; lip acute, columella abruptly arcuate at base. (Baird). Length 12.5 mm. Turn Island and off Shaw Island, Wash., in 25 fathoms; Departure Bay, B. C., in 10-25 fathoms, by Dr. C. M. Fraser.\*—Kodiak Island, Alaska, to Puget Sound.

#### RETUSA Brown, 1827

Shell cylindrical, the spire slightly convex, flat or concave, apex intorted; suture not distinctly channelled. Columella with one fold or none. (Tryon Manual Conch.)

*Retusa harpa* Dall, 1871. (Pl. 15, fig. 11, Amer. Manual Conch., vol. 7). Shell small white, of  $4\frac{1}{2}$  whorls; tabulate and sharply carinate above, characterised by sharp grooves and raised lines parallel with the lines of growth, which extend half over the whorls and become obsolete anteriorly; apex mammillated, minute, globular, prominent, suture canaliculated. Anterior portion of the last whorl smooth. Last whorl slightly narrower above. Aperture long, narrow, effuse below, with a deep narrow sinus at the suture. Columella thickened with a thin layer of white callus, columellar plait obsolete in the adult, rather prominent in young shells. Carina intersected by the grooves and slightly dentate. Length, .24; diameter, .12 inches. (Dall). San Juan, Brown and Turn Islands, Wash.; Departure Bay, B. C., by Rev. G. W. Taylor.—Queen Charlotte Islands to San Diego, Calif.

#### VOLVUELLA Newton, 1891. (Volvula A. Adams, 1850)

Shell subcylindrical, beaked at both ends; spire none; aperture narrow, linear, extending posteriorly beyond the body-whorl, acuminate in front; inner lip with a single obsolete fold at the fore part; outer lip acute, produced and pointed posteriorly. (Arnold). Example *Volvula rostrata* A. Adams.

*Volvuella cylindrica* Carpenter, 1863. Shell cylindrical, white, shining, encircled by distant spiral striae; flattened in the middle, the margins nearly parallel, rather effuse below, suddenly narrowed behind; canal very short; lip acute; inner lip indistinct; columellar fold small,

very sloping. (Carpenter). Length 4.3, diameter 1.8 mm. Departure Bay, B. C., by Rev. G. W. Taylor.—Vancouver Island to Gulf of California.

### Family SCAPHANDRIDAE

#### DIAPHANA Brown, 1827

Shell thin and fragile, capacious or subglobose, umbilicated, the spire either projecting, flat, or sunken in a narrow apical umbilicus. Aperture narrowed above, rounded below, the lip sinuous; columella not thickened, long and rather straight, neither folded nor truncated, its edge a little reflected above. Type *D. minuta* Brown.

*Diaphana brunnea* Dall, 1919. Shell small, yellowish white, of about four whorls, the apex sunken but exposed in a pit bounded by a sharp carina, the shell wider anteriorly; surface with faint incremental lines crossed obliquely by minute vermicular sculpture, which is more nearly spiral about the middle of the shell and visible only under a lens; aperture narrow behind, wider and produced in front, the edge of the outer lip produced to form the apical carina, laterally straight and rounded to the pillar in front; umbilical region covered with a smooth layer of enamel; pillar concave, axis twisted. (Dall). (Off San Juan Island, Wash., and Vancouver Island.\*—Kodiak Island, Alaska, to Puget Sound.

#### CYLICHNELLA Gabb, 1872

Shell oblong-oval; spire concealed, imperforate; columella with a callous fold, and below it a nodule-like fold. (Tryon Manual Conch.) Type *C. bidentata*.

*Cylichnella* (*Bullinella*) *alba* Brown, 1827. (Pl. 19, figs. 43, 44, Brown's Illust. Conch. Gt. Brit.) Shell oblong, somewhat cylindrical, tapering toward both ends. White covered with a pellucid buff cuticle; polished; surface sculptured by extremely close, fine, superficial spiral striae, visible only under a strong lens, on fresh specimens. Aperture narrow above, dilated below, wider than in *C. cylindracea*; the lip curved as in that species. Columella thick but hardly folded. Apex imperforate, somewhat concave, bounded by a keel. Length 5.5, diameter 2.67 mm. (Tryon Manual Conch.)—Arctic Ocean to Monterey, Calif.; circumboreal.

*Cylichnella attonsa* Carpenter, 1865. "Rounded off at apex." (Carpenter). Shell elongate, cylindrical; sides straight; white with a light colored epidermis; with a tracing of orange around the outer

edge of the inner lip. Aperture very narrow for two-thirds of the length, and widening out below. Columella slightly twisted. Sculpture consists of fine hair lines running concentrically around the shell. Length 10, diameter 3 mm. Off San Juan Island, Wash., in 20-25 fathoms.—Puget Sound to Dan Diego, Calif.

### Family AKERIDAE

HAMINOEA Turton, 1830 (Haminea Leach, 1847)

Shell thin and rather fragile, unicolored, corneous, yellowish or greenish, covered with a thin cuticle, globose, ovate or cylindric-oval, the spire sunken and concealed, vertex concave, imperforate or minutely perforate; body whorl large; aperture as long as the shell, broadly rounded below, narrow above; columella simply concave, thin, its edge narrowly reflexed, showing a slight fold where it joins the body of the shell; lip retreating above, but not distinctly sinused. (Description of genus *Haminea* from Manual Conch.) Type *Bulla hydatis* Linne.

*Haminoea vesicula* Gould, 1855. (Pl. 5, fig. 29, Pacific R. R. Surveys, vol. 5, app.) Shell small, fragile, ovate globose, pale greenish yellow; body of the shell small, truncate at summit; outer whorl large; aperture about twice the length of the body of the shell, and projecting above it, broadly rounded both posteriorly and anteriorly; outer lip inflexed at the middle; pillar profoundly arcuate, with a narrow delicate callus. Length,  $3/10$ ; breadth,  $1/5$  inch. (Gould). Brown Island and False Bay of San Juan Island, Wash.\*—Vancouver Island to Gulf of California.

*Haminoea olgae* Dall, 1919. (Plate 5, fig. 12). Shell large, thin, very light yellowish green or reddish brown, inflated, with the outer lip rising high above the sunken and impervious spire; the apical depression not carinate, the axis gyrate and widely pervious; outer lip arcuate, thin, sharp, rounding into the pillar below; axial sculpture confined to low narrow irregular wrinkles, stronger distally; spiral sculpture of minute, close-set, slightly wavy striae over the whole surface; the inner lip with a thin coating of whitish enamel. Height, 27; diameter, 16 mm. (Dall). Olga, Orcas Island, Wash.\*—Orcas Island, Wash., to San Quentin Bay, Lower California.

### Family PHILINIDAE

PHILINE Ascanius, 1772

Shell spiral and moderately developed; foot about two-thirds the length of body, obliquely truncated. (Tryon Manual Conch.)

*Philine polaris* Aurivillius, 1885. (Plate 12, figs. 21, 22, and plate 13, fig. 18, Vega Exped. Vetensk. Iakttag., vol. 4). Shell very thin, fragile, pellucid, oblong-ovate; whorls 3-4. Aperture ample, expanded at base, contracted above, the outer lip more appressed than in *P. finmarchica*. Surface covered with spiral, very delicate pairs of lines, scalloped chain-wise. Alt. 3, diam. 2.5-2 mm. (Tryon Manual Conch.) B. C.—Arctic Ocean to Nanaimo, B. C.

### Family APLYSIIDAE

PHYLLAPLYSIA Fischer, 1872

Body flat, neck short, foot broad, natatory lobes small. Shell absent or horny. (Tryon S. S. Conch.) Type *P. lafonti* Fischer.

*Phyllaplysia taylori* Dall, 1900. The animal is subtranslucent, smooth, of a uniform pale lemon-yellow color, very much flattened, resembling some of the planarian worms. (Dall). Near, Nanaimo, B. C., by Rev. G. W. Taylor.—Known only from Nanaimo, Vancouver Island.

### Family SIPHONARIDAE

SIPHONARIA Sowerby, 1824

Shell ovate, sometimes elevately conical, uncinatate at the top, sometimes depressed, radiately ribbed or striated, denticulated at the margin. Muscular impression interrupted in front, more or less distinctly marked, with a canal leading to the side. (Conch. Iconica). Type *S. sipho* Sowerby.

*Siphonaria* (*Liriola*) *thersites* Carpenter, 1864. (Pl. 4, fig. 8, and pl. 5, fig. 2, Amer. Conch., vol. 6). Shell with strong lungrib and obsolete sculpture. (Carpenter). Long. 46, lat. 33, alt. 17 mm. Vancouver Island, by Rev. G. W. Taylor.—Aleutian Islands to Strait of Fuca.

### Family TURRITIDAE

CLATHRODRILLIA Dall, 1918. (*Drillia*)

For the generally brown or brownish clathrate species a few of which are found in nearly every fauna, and of which *Pleurotomia gibbosa* Reeve may be specified as a typical example, the new name of *Clathrodrilla* Dall may be used. (Dall).

*Clathrodrilla* (*Moniliopsis*) *incisa* Carpenter, 1865. (Plate 18, fig. 3). Shell in general form like *C. ophiderma*, but smaller, the

whorls somewhat more rounded; cinereous, with reddish chestnut revolving lines. Length, 1.13; diameter, .4 inches. (Tryon Manual Conch.) Puget Sound; Victoria, B. C., by Rev. G. W. Taylor.\*—Puget Sound to San Pedro, Calif.

*Clathrodrilla rhines* Dall, 1908. (*Drillia cancellata*). (Plate 5, fig. 4). Shell like a young incisa in form, the spire decorticated, 4 planate whorls remaining, suture distinct, with about twenty small longitudinal ribs crossed by close revolving striae, cancellating the surface, and sometimes the intersections subnodulous. Length, 30; diameter, 9 mm. (Dall). Off O'Neal Island, Wash., in 25 fathoms.\*—Puget Sound to San Diego, Calif.

*Clathrodrilla halcyonis* Dall, 1908. (Plate 18, fig. 1). Shell small, slender, very acute, of a livid purple covered with an olivaceous periostracum, with about 11 whorls; nucleus more or less eroded, but apparently smooth, acute, and including about  $2\frac{1}{2}$  whorls; subsequent whorls rather flat, compressed and appressed at and in front of the suture, with a rounded base and inconspicuous anal fasciole; sculpture chiefly of flattish spiral threads, one at the suture, 3 smaller ones in front of it, followed by a flat broader one representing the fasciole, then (on the last whorl) 8 more prominent threads, undulate or segmented by incremental lines and with wider interspaces (sometimes containing an intercalary smaller thread) to the base, followed by 6 or 7 unsegmented threads to the siphonal fasciole, which bears 6 or 7 smaller threads; the succession of undulations or slightly swollen segments give a slightly cancellate effect to the part of the whorl which bears them, but there are no axial ribs, the effect being produced rather by depressions between the rather coarse incremental lines; aperture narrow, acute behind, the anal sulcus narrow and distinct but not deep, the outer lip in front of it arcuately produced, the canal contracted, short, and recurved; inner lip polished and superficially erased; the pillar twisted, with a thin layer of callus; operculum present as in *C. ophioderma*. Height of shell, 23; of last whorl, 12.5; of aperture and canal, 8; maximum diameter, 7 mm. (Dall). Off Lopez Island, Wash.; Burrard Inlet, B. C.\*—Burrard Inlet, B. C., to San Diego, Calif.

#### ANTIPLANES Dall, 1902

Shell smooth except for incremental lines and sometimes fine spiral striae, the periostracum is conspicuous and the shell disposed to be chalky, the anal sulcus shallow and more or less rounded, usually situated some distance from the suture, but not quite on the periphery

of the whorl, the canal rather wide and long and often a little recurved, the aperture unarmed. There are both dextral and sinistral species. (Dall). Type *Surcula perversa* Gabb.

*Antiplanes perversa* Gabb, 1865. (Plate 8, fig. 3). Shell small, sinistral, elongate, slender; spire high, apex usually bent to one side; whorls 11 to 12, convex, 2 nuclear whorls rather loosely twisted and more convex than the others; sculpture deep; body whorl nearly half of the entire length of the shell. Aperture broadest in the middle, narrowing regularly in advance; inner lip moderately incrustated; outer lip simple; sinus rather broad, shallow, rounded, and adjoining the suture; canal of variable length, often much larger than in the specimen figured. Color, in living specimens, a light reddish-brown. (Gabb). Length 38, diameter 11 mm. Off San Juan Island, Wash., in 25-30 fathoms.\*—Forrester Island, Alaska, to Cortez Bank, Lower California.

LORA Gistel 1848. (Bela)

Shell oblong-ovate, somewhat solid, white; whorls slightly convex; lip flaring, small, coated internally with callus; aperture expanding in front. (Free translation).

*Lora kyskana* Dall, 1919. (Plate 18, fig. 2). Shell belonging to the group of *L. fidicula* Gould, but with looser and less regular sculpture, white, the nucleus defective, with about 6 shouldered whorls; suture distinct, anal fasciole obscure, undulated by the ends of the ribs, spirally striated; axial sculpture of (on the last whorl 14 or 15) rounded ribs with wider interspaces, prominent at the shoulder, crossing the whorls at the spire, obsolete on the base; spiral sculpture of numerous narrow channeled grooves with wider flattish interspaces, not nodulating the summits of the ribs; on the spire the interspaces are more cordlike, 6 or 7 between the shoulder and the succeeding suture; aperture simple, inner lip erased; canal short, straight. Height of shell, 10.5; of the last whorl, 7; diameter, 4.5 mm. (Dall). Puget Sound.—Aleutian Islands to Puget Sound.

*Lora quadra* Dall, 1919. (Plate 18, fig. 6). Shell short and stout, white, with about 5 whorls, the apex eroded, suture distinct, the anal fasciole narrow, excavated, finely spirally striated; axial sculpture of (on the last whorl about 18) stout nearly vertical ribs angulated at the edge of the fasciole, forming a narrow shoulder, but without a limiting cord, with usually narrower interspaces and obsolete on the base, the incremental lines not conspicuous; spiral sculpture of spiral grooves with much wider flat interspaces, the canal

constricted, spirally threaded, very short; aperture simple, inner lip erased. Height of shell, 8; of last whorl, 6; diameter, 4.5 mm. (Dall). Puget Sound.—Unalaska, Alaska, to Puget Sound.

*Lora tabulata* Carpenter, 1865. (Plate 18, fig. 5). "Testa parva, solidissima, luride rufo-fusca, marginibus spirae excurvatis; vertice nucleoso chalconico (eroso); anfr. norm. v., postice rectangulatum tabulatis, suturis impressis; costis radiantibus circ. xvi., validis, obtusis, circiter basim attenuatam obsoletis; costis spiralibus in spira iii.-lv. angustis, extantibus, supra cost. rad. nodosis; interstitiis alte insculptis, subquadratis; costis circa basim circiter vii., quadratum extantibus, interstitiis a lineis incrementi vix decussatis; canali curti, aperta; labro acutiore, ad angulum posticum vix sinuato; labio tenui; columella obsolete uniplicata." Shell stout, strongly shouldered, coarsely cancellated. Pillar abnormally long, twisted. (Carpenter). Length about 13 mm. Neah Bay, Wash.—Sitka, Alaska, to San Pedro, Calif.

*Lora fidiola* Gould, 1849. (Plate 5, fig. 2). Whorls 7, broadly shouldered; about 24 longitudinal plications, crossed and decussated by more crowded delicate revolving lines; dirty-white. Length 0.45 in. (Tryon Manual Conch.) Off O'Neal and Lopez Islands, Wash.; between Trail Island and the mainland of B. C. near Seechelt.\*—Adak Island, Aleutian Islands, to Bellingham Bay, Wash.

*Lora pleurotomaria* Couthouy, 1838. (Pl. 1, fig. 9, Boston Journ. Nat. Hist., vol. 2). Shell fusiform, elongated, tapering to an acute point, of a uniform fawn-color, sutures distinct, whorls 7 to 9, covered with rounded undulating ribs or plaits, to the number of 18 upon the lowest, alternating with each other at the sutures, and most prominent on the superior whorls; in some instances these folds become obsolete about midway on the body-whorl, which is nearly half the length of the shell, with delicate, transverse striae near the middle; in some individuals these striae are apparent on all the whorls; outer lip tranchant, smooth internally, the edge forming a regular outward curve; a slight compression is perceptible about its middle portion; columella arcuated superiorly, its inferior third inclining, rather abruptly, to the left; aperture an elongated oval, terminating in a brief sub-ascending canal. Length, 16/20; diameter of last whorl, 11/40 of inch. (Couthouy). Puget Sound.—Nunivak Island, Bering Sea, to Puget Sound; Atlantic.

*Lora harpularia* Couthouy, 1838. (Pl. 1, fig. 10, Boston Journ. Nat. Hist., vol. 2): Shell oblong, fusiform, turreted, color yellowish-brown, whorls 6 to 8, convex, slightly angular superiorly, and planu

lated at the suture, which is clearly defined; they are transversed by numerous, oblique, rounded ribs, to the number of 19 on the body-whorl, whose interstices are filled with delicate but distinct, transverse striations, extending nearly across the ribs; aperture elongated, oval, rendered somewhat angular at the outer, superior extremity, by the planulation of the body-whorl; lip sharp and smooth internally; columella smooth, arcuate, with a slight callus upon its inferior portion; canal short and inclined to the left. Length, 11/20; diameter of last whorl 5/20 inch. (Couthouy). Puget Sound.—Point Belcher, Arctic Ocean, to Puget Sound; circumboreal.

*Lora miona* Dall, 1919. (Pl. 14, fig. 2, Proc. U. S. Nat. Mus., vol. 56) This is another species of the fidicula group, white, small, roundly shouldered with rather coarse sculpture on the spire, which becomes obsolete on the last whorl; axial sculpture of (on the penultimate whorl 13) rounded irregular ribs with subequal interspaces, the ribs nodulate by the intersection of 3 or 4 rather strong spiral cords with narrower interspaces; on the last whorl the ribs are obsolete and the spiral sculpture feebler, flatter, and with occasional intercalary smaller threads; anal fasciole and sulcus obscure, aperture narrow, inner lip erased, canal short. Height of shell, 8; of last whorl, 5; diameter. 3.5 mm. (Dall). Friday Harbor, Wash., by C. C. Engberg.—Boca de Quadra, Alaska, to Point Reyes, Calif.

• *Lora maurellei* Dall & Bartsch, 1910. (Plate 12, fig. 5). Shell small, fusiform, greenish white, with about 6 whorls. First whorl of the nucleus, flattish, minute, apparently smooth; second whorl with a sharp prominent shoulder-keel, crossed by numerous minute riblets, much lower than the keel. On the next whorl the periphery bears a keel like that at the shoulder, and the riblets gradually become stronger, and fewer in number, diminishing, however, on the following whorls to mere axial striations; the peripheral keel also losing its prominence. On the latter whorls, which still preserve—though with less prominence—the keel at the shoulder, the spiral structure becomes predominant, and on the spire there are about 4 spiral threads between the shoulder and the suture in front of it, and on the last whorl about 10 between the shoulder and the beginning of the canal, which is also spirally striated. The prominent shoulder gives a turreted aspect to the whorls; the aperture being narrow; the outer lip sharp; the anal sulcus shallow and feeble; the pillar white, and attenuate in front; and the canal short and wide. Height of (not quite mature) shell, 8.5; of last whorl, 5.5; of aperture, 4; maximum



diameter, 3.5 mm. (Dall & Bartsch).—Known only from Barkley Sound, Vancouver Island.

*Lora lotta* Dall, 1919. (Pl. 14, fig. 4, Proc. U. S. Nat. Mus., vol. 56). Shell small, white, with a pale straw-colored periostracum, nucleus eroded, 4 whorls remaining, the general characters resembling those of *L. surana*, but the axial sculpture nearly obsolete, or quite absent from the last whorl, the shoulder less accented, and the canal straighter. Height of shell, 7.5; of last whorl, 6; diameter, 4 mm. (Dall). Queen Charlotte Islands.—Queen Charlotte Islands to San Diego, Calif.

*Lora harpa* Dall, 1884. (Pl. 4, fig. 2, Proc. U. S. Nat. Mus., vol. 9). Shell fusiform, moderately thin, 6 whorled; whorls rounded, suture distinct; sculpture consisting of (on the last whorl) 23 stout, uniform, slightly flexuous rounded ribs extending from the suture to the canal with slightly narrower interspaces; lines of increase distinct; sometimes threadlike; these are crossed by numerous close-set spiral threads, separated by narrow grooves, both faint near the suture; threads growing stronger, regularly wider, and coarser gradually toward the canal, near which they are stronger than the obsolete ends of the transverse ribs; anal fasciole (notch band) indistinct, aperture narrow, elongated with an acute posterior angle, outer lip thin, columella simple, canal rather wide; shell whitish, with a reddish tinge anteriorly, especially on the last whorl; interior of aperture reddish, of the canal pure white. Longitude of shell, 17; of last whorl, 12.5; of aperture, 10 mm. (Dall). Queen Charlotte Islands.—Arctic Ocean to Queen Charlotte Islands; circumboreal.

*Lora turricula* Montagu, 1803. (Pl. 3, fig. 17, Montagu's Testacea Brit.) Shell narrow, turriculated, the shoulder acute, with the ribs strongly projecting above it and then running across to the sutures; ribs about 16, nearly straight, prominent, crossed by very close, rather fine revolving striae; aperture rather narrow; canal narrow and produced. Length, 17 mm. (Tryon Manual Conch.) Off San Juan Island and off entrance to East Sound, Wash.\*—Icy Cape, Arctic Ocean, to Puget Sound; circumboreal.

*Lora rosea* M. Sars, 1846. (Plate 5, fig. 1). Shell elongate, spire high, sharp; whorls 8, evenly sculptured with strong longitudinal ribs and faint spiral lines. Sutures well defined, shoulders slightly rounded. Aperture elongate; columella slightly curved on the upper half. The original description was not available, and I have written one from specimens collected. Length 23, breadth 8mm. Griffin Bay,

San Juan Island, Wash., in 25 fathoms.\*—Simeonof Island of the Shumagin group, Alaska, to San Juan Island, Wash.; circumboreal.

*Lora pribilova* Dall, 1919. (Pl. 16, fig. 3, Proc. U. S. Nat. Mus., vol. 56). Shell white with a straw-colored periostracum and about 6 roughly sculptured whorls, the apex eroded; suture distinct, axial sculpture of (on the last whorl 16) rounded narrow riblets crossing the whorls and obsolete on the base; spiral sculpture of (on the spire 3, on the last whorl 4) prominent rounded cords more or less nodose at the intersection with the ribs, and between the cords 2 or 3 fine threads and a few finer striae; the posterior cord forms a shoulder to the whorl; on the canal the cords and threads become more uniform; aperture simple, pillar erased. Height of shell, 12; of last whorl, 8; diameter, 5.5 mm. (Dall). Departure Bay, B. C., by Rev. G. W. Taylor.\*—Cape Lisburne, Arctic Ocean, to Esteros Bay, Calif.

*Lora solida* Dall, 1886. (Pl. 3, fig. 4, Proc. U. S. Nat. Mus., vol. 9). Shell solid, short, stout, with 5 strongly sculptured whorls and a small smooth nucleus; color a faint blush of salmon covering the white; epidermis very thin, smooth, and adherent; transverse sculpture of, on the last whorl, 13 stout, shouldered, prominent, rather sharply rounded ribs, which pass over the periphery and disappear at the anterior third of the whorl; they cross the anal fasciole with but little flexure, but curve forward from the angulation (generally more decidedly than the figure indicates), at which they are somewhat swollen, with about equal interspaces; longitudinal sculpture of numerous equal uniform grooves, with convexly rounded subequal interspaces, faint on the anal fasciole, but covering the rest of the shell with remarkable uniformity, averaging 5 or 6 to the space of a millimeter; one or 2 stronger ones follow the angulation of the whorl, but not prominently; pillar stout, white; anal notch obsolete; operculum short, broad, thin, yellowish. Greatest length of shell, 13; of aperture, 8; greatest breadth of shell, 7 mm. (Dall). Alert Bay, B. C.\*—Bering Strait to Puget Sound.

*Lora alaskensis* Dall, 1871. (Pl. 4, fig. 3, Proc. U. S. Nat. Mus., vol. 9). Shell elongate, fusiform, of a reddish or purplish brown, of 8 evenly rounded whorls; aperture less than half and more than a third as long as the shell, rather narrow; outer lip thin, sharp; columella straight, with a slight callus; canal short, wide, very slightly recurved; sutural sinus obsolete. Sculpture of almost imperceptible revolving lines, crossed by oblique longitudinal ribs, waved near the suture and obsolete on the lower half of the whorl. Lines of growth

irregular, quite evident; epidermis thin, olivaceous; whorls slightly shouldered; nucleus and the first few small whorls whitish; nucleus smooth, obliquely bent, minute; suture deep, impressed; a slight callosity on the columella. Interior of the aperture polished, smooth, fuliginous. Ribs rather strong on the upper whorls. Lon. 0.8, Lat. 0.3 inch. (Dall).—Bering Strait to Puget Sound.

MANGILIA Risso, 1826

Shell fusiform, imperforate; aperture oval-elongate, usually narrow, terminating in a rather short, truncated canal; lip sinus near the suture. No operculum. (Tryon Manual Conch.) Type *M. costulata* Risso.

*Mangilia barbarendis*; a new name for *M. angulata* Carpenter, 1865, not *M. angulata* Reeve, 1846. (Pl. 7, fig. 9, Arnold's Paleont. San Pedro). Shell small, turreted, elongate-fusiform; apex acute; whorls 6, broad and angular, angle being slightly posterior to the middle; sculpture consists of 10 prominent, rather sharp transverse ridges, which reach maximum prominence on the angle of whorl; suture deeply impressed, distinct; aperture oblique, narrow, elliptical, drawn out anteriorly into a short, narrow canal; outer lip thin, simple, arcuate; inner lip smooth. (Arnold). Length 8 mm. Puget Sound.—Puget Sound to Gulf of California.

*Mangilia sculpturata* Dall, 1886. (Pl. 4, fig. 7, Proc. U. S. Nat. Mus., vol. 9). Shell 7-whorled, turritid, white, with strong waxy yellow epidermis; thin with strong sculpture; transverse sculpture of, on the last whorl, 10 strong squarish ribs and numerous fine and occasionally impressed lines of growth; longitudinal sculpture of a distinct angulation of the whorl, in front of the anal fasciole, which on the transverse ribs develop into stout swellings, which in the earlier whorls are connected by an obscure rib; the whole surface of the whorl is covered with rather wide and shallow grooves and their even wider interspaces; the grooves are closest and finest on the canal and behind the angulation, and faintest or nearly absent on the periphery; anal notch very shallow, fasciole nearly obsolete. Operculum short, triangular, yellowish brown. Length, 12.3; breadth, 4.5 mm. (Dall). Lone Inlet and Gabriola Island, B. C.\*—Chiachi Island, Alaska Peninsula, to Vancouver Island.

*Mangilia aleutica* Dall, 1871. (Plate 19, fig. 1). Shell pure white, elongated, acuminate, of 7 whorls carinated above, though not very strongly. Aperture narrow, long, two fifths the length of the

shell; outer lip sharp, thin, strongly flexuous, produced below, sinus close to but not on the suture, not very deep or prominent; canal one-third as long as the aperture, straight, narrow; columella smooth, almost straight, without callus; nucleus smooth white, pointed, drawn out; sculpture consisting of longitudinal ribs 13 or 14 on the last whorl, obsolete on the lower third of the whorl and not extending to the suture, below which is a smooth band only marked by oblique lines of growth; ribs slightly nodulous at their posterior terminations (where they are united by a slight carina) strong on the upper whorls, slightly flexuous on the convexity of the whorl. Whorl below the carina marked by very faint grooves close together and passing over the ribs, stronger at the anterior end of the last whorl. Lon., 0.68; lat., 0.24 in. (Dall).—Arctic Ocean to Strait of Fuca.

*Mangilia carlottae* Dall, 1919. (Plate 46, fig. 7). Shell small, thin, snow white, with a swollen smooth nucleus of 2 whorls and 6 subsequent whorls; suture distinct, not appressed; the anal fasciole sloping forward flatly to the shoulder of the whorl with only arcuate incremental lines for sculpture; axial sculpture of (on the last whorl about 20) obliquely protractive short ribs, strongest at the shoulder and on the last whorl stopping abruptly near the periphery; spiral sculpture hardly perceptible, on the base are a few distant obsolete threads and faint microscopic striae; these vary in strength in different specimens; anal sulcus rounded, wide and shallow; outer lip thin, sharp, arcuately produced; aperture narrowly ovate, inner lip erased; pillar and canal short, the latter wide and hardly differentiated. Height of shell, 9; of last whorl, 5.5; diameter, 4 mm. (Dall).—Known only from off Queen Charlotte Islands, in 867 fathoms.

*Mangilia criopis* Dall, 1919. (Plate 19, fig. 3). Shell small, white, polished, having a nucleus with an oblique smooth small apex and about one whorl, the latter part spirally striated, and about 6½ subsequent whorls; spire acute, slender, the whorls moderately rounded, the suture distinct, not appressed; spiral sculpture of a few obscure threads on the back of the canal and on the apical whorls; axial sculpture of (on the last whorl about 15) sigmoid ribs, most prominent at the shoulder; feeble over the anal fasciole and on the base; aperture narrowly ovate, anal sulcus shallow and wide, beginning at the suture; outer lip produced, thin and sharp; inner lip and pillar with a thin wash of enamel; pillar straight, attenuated in front, canal short and narrow. Height of shell, 13.5; of last whorl, 7.5; diameter, 5 mm. (Dall).—Forrester Island, Alaska, to Queen Charlotte Islands.

*Mangilia newcombei* Dall, 1919. (Pl. 21, fig. 4, Proc. U. S.

Nat. Mus., vol. 56). Shell small, brownish, with a tendency to banding, paler at the shoulder and on the base, with 6 whorls, including a small, smooth nuclear whorl; suture distinct, slightly appressed, with no fasciolar constriction; spiral sculpture of fine flattish threads separated by narrow striae very minutely reticulated by the incremental lines and most conspicuous in the intervals between the ribs, practically covering the whole surface of the shell; axial sculpture, besides almost microscopic lines of growth, of (on the last whorl 14) short rounded ribs, slightly angulated at the shoulder and extending from the suture to the canal with subequal interspaces; anal sulcus shallow, aperture narrow, simple, inner lip erased, canal short, straight. Height of shell, 11; of last whorl, 7; diameter, 4 mm. (Dall). Vancouver Island, B. C.—Vancouver Island to Drake's Bay, Calif.

*Mangilia arteaga* Dall & Bartsch, 1910. (Plate 13, fig. 4). Shell small, acute-fusiform, having about 8 whorls, the initial whorl extremely minute, subsequent whorls slowly enlarging, minutely reticulate. The later whorls have a strongly marked shoulder, and are, when young, of a reddish-brown colour, which gradually changes with exposure to a light gray. The sculpture of the adult whorls consists of (on the last whorl about 10) prominent, slightly arcuate, nearly avial ribs, rather sharply nodose at the intersection with the angle of the shoulder, with wider interspaces and continuous to the canal. As to the spiral sculpture of major and minor threads, there are about 10 of the former in front of the shoulder of which 2 are visible behind the suture on the spire; the remainder, which are much finer and minutely rugose, occupy the interspaces of the whole surface, the major threads being slightly swollen where they cross the ribs; aperture narrow; anal sinus shallow, and small; pillar and throat brownish, with a brown obscure band under the suture; outer lip sharp between and thickened at the varices; canal short and wide; operculum none. Height, 10.25; of last whorl, 6.5; aperture, 4.6; maximum diameter, 4 mm. (Dall & Bartsch). Barkley Sound, Vancouver Island.—Vancouver Island to San Diego, Calif.

*Mangilia hecetae* Dall & Bartsch, 1910. (Plate 12, fig. 6). Shell small, thin, acute-fusiform, externally of a grayish colour. Whorls about 7, the initial whorl minute and smooth; the second bulbous and smooth; the next finely reticulated by fine spiral threads, and somewhat protractive arcuate fine riblets. This sculpture gradually merges into that of the adult whorls; the latter comprise—on the last whorl—11 or 12 arcuate ribs, retractive from the suture, protractive from the shoulder of the whorl forward to the canal. The ribs are nar-

row, low, rather rounded, and with interspaces of about twice their own width. The whorl slopes in a somewhat excavated manner from the suture to the shoulder, where there is a moderate angulation, sometimes forming a rather strong spiral cord; the rest of the surface is covered with very fine, close, even, spiral threading, a little coarser on the earlier whorls; aperture elongate and narrow; the anal sinus wide and shallow; pillar white, with anterior end attenuated; interior of aperture white, with 3 brown spiral bands, wide and dark, on the inside of the outer lip, but not visible on the exterior of the shell; the outer lip is sharp except when varix is formed, when it is slightly reflected inward; operculum none. Height of shell, 9; of last whorl, 5.3; of aperture, 4.5; max. diam., 3.25 mm. (Dall & Bartsch). Barkley Sound, Vancouver Island.—Vancouver Island to San Diego, Calif.

*Mangilia crebricostata* Carpenter, 1865. Shell slender, fusiform, white, with a brown band on the anal fasciole, and another a little in front of the periphery, the latter most conspicuous on the last whorl; nucleus smooth, initial part very small, the apex flattened, the whole nucleus of about two whorls, followed by five and a half sculptured whorls; axial sculpture of (on the last whorl 15) uniform, flexuous, low, rounded ribs, attenuated on the fasciole, undulating the suture between the earlier whorls and rapidly becoming obsolete on the base of the last whorl; spiral sculpture of fine striae on the fasciole, in front of it sharp grooves with wider interspaces which at first are threadlike, later flattened, and on the last whorl are reduced to rather close-set, feeble, fine spiral striae; suture appressed; anal notch feeble; canal short, straight, with no siphonal fasciole; aperture narrow, elongate; outer lip thin, sharp; pillar lip smooth, white, polished, attenuated at the canal; operculum absent. Length, 12; diameter, 4.25 mm. (Dall & Bartsch). Banks Island and Station 25, B. C.\* by Dr. C. M. Fraser. Forester Island, Alaska to Monterey, Calif.

*Mangilia interfossa* Carpenter, 1865. "M. testa parva, valde attenuata, rufo-fusca, marginibus spirae parum excurvatis; anfra. nucl. ii., ut in Chrysodomo irregularibus, apice mamillato; norm. vi., parvum excurvatis, haud tabulatis, suturis distinctis; costis radiantibus circ. xv., angustis, extantibus; costulis spiralibus circ. v. seu vi. in spira monstrantur, angustis, supra costas transeuntibus, ad intersectionem parum nodulosus; interstitiis altis, quadratis; basi effusa; apertura subpyriformi; labro acuto, postice vix emarginato; labio tenui." (Carpenter). Scarcely very narrowly shouldered, with about 15 narrow longitudinal ribs, separated by wider interspaces, and the same num-

ber of spiral lirae, forming subquadrangular pits between the sculpture; reddish brown. Length, 10 mm. (Tryon Manual Conch.) Vancouver Island, B. C.—Vancouver Island to Catalina Island, Calif.

*Mangilia levidensis* Carpenter, 1865. (Plate 5, fig. 3; plate 45, fig. 4). Stumpy, purplish brown, with rough sculpture. (Carpenter). Carpenter's types from Neah Bay and Puget Sound were badly worn, imperfect specimens, hardly identifiable. The color of the fresh shell is dark brown, and the sculpture on the last whorl in senile specimens is often more or less obsolete. Height of shell, 16; diameter, 6 mm. (Dall). Off Brown Island, Wash., in 25 fathoms.—Bering Strait to Monterey, Calif.

#### CYTHARELLA Monterosato, 1875

These are the small species with thickened but not lirate or denticulate outer lip and pillar; the spire usually shorter than the aperture, the surface longitudinally ribbed, smooth, or spirally minutely sculptured; nucleus small, smooth. (Dall). Type *Pleurotoma bertrandi* Payraudeau.

*Cytharella victoriana* Dall, 1897. (Plate 45, fig. 14). Shell small, solid, brownish or livid purple, with 6 whorls; spire rather acute, nucleus worn but apparently smooth, the succeeding whorls sculptured with strong flexuous, discontinuous ribs, which cross from suture to suture; the interspaces are wider than the ribs, of which there are 9 on the last whorl; suture distinct, somewhat appressed and undulated by the ends of the ribs; aperture long, narrow, with a wide, strong anal notch, the outer lip strong and heavy; pillar smooth, canal short, not recurved. Length of shell, 7; maximum diameter, 3 mm. (Dall).—Known only from near Victoria, Vancouver Island.

#### Family CANCELLARIIDAE

##### CANCELLARIA Lamarck, 1799

Shell oval, cancellated, reticulated or ribbed; last whorl ventricose; aperture oblong, canalculated in front; canal short, sometimes recurved; columella with several large oblique plications. (Tryon Manual Conch.) Type *C. cancellata* Linne.

*Cancellaria* (Sveltia) *modesta* Carpenter, 1865. Shell elevated, reddish, margins of the spire straight; whorls normal or rotund, subtabulate in the rear, with impressed sutures, with obtuse spiral ribs, distant, about 4 to a whorl, on the body-whorl about 7, frequently

with smaller ones intercalated; with channels crossed by growth lines; aperture subquadrate, with two inclined plications in front, and a minute basal rib. Length 31, diameter 14 mm. Off San Juan Island, Wash., in 20-25 fathoms.\*—Aleutian Islands to Puget Sound.

*Cancellaria* (Sveltia) *unalashkensis* Dall, 1873. (Pl. 2, fig. 1, Proc. Calif. Acad. Sci., vol. 5). Whorls 6, somewhat turreted, with strong revolving ridges, decussated on the spire, and upper portion of the body-whorl by longitudinal riblets, the intersections of the riblets and ridges nodulous; white, with traces of a nut-brown epidermis. Length, 12; diameter, 6 mm. (Tryon Manual Conch.) Off Lopez Island, Wash., in 25 fathoms. Two specimens.\*—Unalaska, Alaska, to Cape Blanco, Oreg.

#### ADMETE Kroyer, 1842

Shell oval, thin, diaphanous, covered by a thin epidermis; spire sharp; last whorl ventricose; aperture oval, feebly channeled in front; columella arcuated, obliquely truncated, with rudimentary plications; outer lip sharp. (Tryon Manual Conch.)

*Admete couthouyi* Jay, 1839. (Plate 20, fig. 10). Shell ovately conical, white, reticulated with coarse revolving lines, and lines of growth; columella three-plaited. (Reeve). Length 16, diameter 8 mm. Off San Juan Island, Wash., in 25-30 fathoms; Lone Inlet, B. C.\*—Arctic Ocean to San Diego, Calif.; circumboreal.

*Admete couthouyi laevior* Leche, 1878. Shell larger than the typical, smoother, suture not as distinct, whorls rounded. Length 15, diameter 9 mm. Off San Juan Island, Wash., in 20-30 fathoms.—Arctic Ocean to Sea Lion Rock, Wash.

### Family OLIVIDAE

#### OLIVELLA Swainson, 1840

Shell polished, small; spire produced, acute, suture canaliculated; aperture narrow behind, enlarged anteriorly; columella plicated in front, callous posteriorly. (Tryon S. S. Conch.) Type *O. undatella* Lamarck.

*Olivella biplicata* Sowerby, 1825. (Plate 22, fig 1). Shell abbreviately ovate, thick, stout, slightly striated longitudinally; spire short; columella arched, smooth, callous at the upper part, two-plaited at the base; aperture effused at the base; bluish-gray, suture brown, columella and base violet, aperture blue-gray, violet at the edge.



(Conch. Iconica). Length 26, diameter 12 mm. Vancouver Island, by Dr. C. M. Fraser.\*—Vancouver Island to Lower California.

*Olivella biplicata fucana* T. S. Oldroyd, 1921. (Plate 22, fig. 2). Shell broader across the middle and lower part of the aperture than var. *angelena*; spire running more sharply to a point from the middle of the shell. Color more uniform, being a light drab. Length, 28; breadth, 14 mm. (T. S. Oldroyd). West side Vancouver Island, by Rev. G. W. Taylor.\*—Vancouver Island to Strait of Fuca.

*Olivella boetica* Carpenter, 1864. (Plate 22, figs. 7, 8). Spire moderately elevated, sharp-pointed, body-whorl oval; red-brown or gray, fasciculated upon a white band at the suture; body-whorl maculated or with zigzag markings, and sometimes a white central band, fasciole white, tip of spire frequently dark tinted. Length 0.75-1 inch. (Tryon Manual Conch.) Off San Juan Island, Wash., and Departure Bay, Vancouver Island.\*—Kodiak Island, Alaska, to Cape San Lucas, Lower California.

*Olivella pedroana* Conrad, 1855. (*O. intorta*). (Pl. 6, fig. 51, Pacific R. R. Repts., vol. 5; also pl. 14, fig. 62, Tryon & Pilsbry's Manual Conch., vol. 5). Shell small, elliptical; spire conical, about equal in length to the aperture; base of columella with a prominent fold. (Conrad). Length 11-15 mm. Puget Sound.\*—Puget Sound to Cape San Lucas, Lower California.

### Family MARGINELLIDAE

CYPRAEOLINA Cerulle-Irelli, 1911. (Merovia)

Shell minute, bulliform, spire sunken; aperture long, the outer lip sometimes denticulated within and extending above the spire; with four plaits anteriorly, and with smaller ones behind them, becoming obsolete. (Oldroyd). Type *Marginella clandestina* Brocchi.

*Cypraeolina pyriformis* Carpenter, 1865. Shell small, pyriform, sometimes tinged with orange; aperture long and narrow, with the outer lip extending above the spire. Columella plates rather acute, 4 in number. Length 2 mm. False Bay, San Juan Island, and Olga on Orcas Island, Wash.\*—Peril Strait, Alaska to Mazatlan, Mex.

### Family MITRIDAE

MITROMORPHA A. Adams, 1865

Shell small, elongately fusiform; whorls flattened, with revolving lirae, and sometimes longitudinally plicate. Aperture narrow; col-

umella straight, slightly transversely lirate; lip acute, smooth within, scarceful sinuated posteriorly. It is a mitriform *Daphnella*, of small size, with lirate whorls. (Tryon S. S. Conch.)

*Mitromorpha gracilior* Hemphill, 1884. (Pl. 25, fig. 62, Tryon & Pilsbry's Manual Conch., vol. 6). Decussation not so deep, so that the surface is smoother, the tuberculation smaller; sometimes the clathration of the body-whorl is only seen on the upper portion, the longitudinal costulae becoming obsolete below. Length, 4-5 mm. (Tryon S. S. Conch.)—Forrester Island, Alaska, to San Diego, Calif.

### Family FASCIOLARIIDAE

FUSINUS Rafinesque, 1815. (*Fusus*)

"Shell fusiform; spire long, acuminate, many-whorled; aperture oval, usually striate within; outer lip simple; columella smooth; no-umbilicus; canal long and straight." (Arnold).

*Fusinus munksae* Dall, 1915. (*F. robustus* Trask). "Shell of medium size, elongate-fusiform, thick; whorls about 6, convex, crossed by 8 or 9 prominent rounded ridges which are most prominent on angle of whorl (these ridges are sometimes obsolete on the anterior part of the body-whorl); spiral sculpture consists of 4 to 6 prominent raised lines, with sometimes smaller lines intercalated; suture appressed, deep, distinct; aperture pyriform; outer lip smooth on inner edge, but with numerous spiral ridges further in; inner lip smooth; columella spirally ridged externally; canal rather short, narrow." (Arnold). Length, 34; height, 14; body-whorl, 22.5; aperture, including canal, 17; canal, 5 mm. Banks Island, B. C.—Banks Island, B. C., to Pequena Bay, Lower California.

### Family CHRYSODOMIDAE

BERINGIUS Dall, 1879

Shell dextral, large, solid, the spire usually longer than the aperture; the sculpture very variable but usually strong; the periostracum thin; dehiscent; the nucleus swollen, with several hardly increasing whorls forming a subcylindrical tip to the spire in most cases; aperture of moderate size, the outer lip slightly expanded and hardly thickened; pillar smooth, short, callous; canal short, wide, hardly recurved; operculum smaller than the aperture, subovate with apical nucleus. The ovicapsules are pouch-shaped, pedunculate, attached by the edge of the disk and opening at the upper edge, with few embryos. (Dall).

*Beringius crebricostatus undatus* Dall, 1919. (Plate 8, fig. 5). Specimens (mostly young) differing from the typical form in having about 17 arcuate rounded ribs extending from the constricted suture to the periphery, and obsolete on the base; there are also more numerous (about 18) spiral ridges, smaller and of course much closer together than in the case of the typical form. Length of the 5 complete whorls, 78; diameter, 35 mm. (Dall). Off San Juan Island, Wash., in 25-30 fathoms.\*—Unalaska, Alaska, to Puget Sound.

*Beringius kennicottii* Dall, 1907. (Pl. 35, fig. 3, Proc. U. S. Nat. Mus., vol. 24). Shell of 6 whorls, which are rather shouldered but not at all carinated. Aperture half the length of the shell or a little less. Outer lip strongly arched, forming a right angle with the body whorl, somewhat effuse anteriorly. Columella with a thick white callus, with a groove behind it, somewhat arched and twisted. Siphonal fasciole well marked, rather narrow. Canal narrow, recurved, rather elongated. Color of the shell white, with a purple tint within. Sculpture consisting of more faint, primary, revolving ridges, obsolete on the convexity, and more evident on the anterior part of the last whorl; absent on the upper whorls. Secondary sculpture of fine crenulated threadlike lines, about 80 to the inch, which are decussated by the lines of growth. The last whorls are crossed by stout, waved, rounded ribs (12 on the last whorl), which are evanescent on the anterior portion of the last whorl, roundly shouldered on the last whorl, less so on the upper ones; their anterior declivity rather sharper than their posterior slope. These ribs are a little wider than the interspaces. Epidermis yellowish brown, thin, smooth, following the sculpture of the surface. Length, 4.5; diameter, 2.5 inches. (Dall). Outside the harbor at Victoria, B. C., by Dr. C. F. Newcombe.—Aleutian Islands to Strait of Fuca.

#### EXILIA Conrad, 1860

Shell elongate, very slender, with numerous whorls, chrysodomoid nucleus, and a very straight canal; periostracum conspicuous, polished; sculpture of numerous fine flexuous axial ribs and spiral striation; aperture small, simple, not lirate within, outer lip thin, sharp, not reflected; inner lip and pillar smooth, without plications or denticles of any sort; operculum long, slightly arcuate, with apical nucleus. Type *E. pergracilis* Conrad.

*Exilia rectirostris* Carpenter, 1865. (Plate 19, fig. 2). Shell small, turreted, slender; apex acute; whorle 9 or 10, slightly convex, with about 14 rounded, transverse ridges reaching from suture to

suture; ridges follow direction of lines of growth, which are convex anteriorly; spiral sculpture consists of numerous fine furrows; suture impressed, distinct; body-whorl slightly angulated at base; aperture elliptical; outer lip thin, bulging above the canal; outer lip smooth, incrustated; columella long, straight, narrow, smooth on inner part; canal long, straight, narrow. (Arnold). Carpenter did not publish a description. Length 28, height 7, body-whorl 14.5; aperture, including canal, 11.5 mm. Near Victoria, B. C., by Dr. C. F. Newcombe; Departure Bay, B. C., by Rev. G. W. Taylor.\*—Behm Canal, Alaska, to Cape San Quentin, Lower California.

#### COLUS Bolten, 1798

Shell long-fusiform, slender, with numerous moderately rounded whorls, the nucleus chrysodomoid, the shell structure usually white, often with a chalky external layer under a conspicuous, usually brownish, adherent periostracum; sculpture spiral, seldom very strong, sometime nearly obsolete, never axially plicate or ribbed; aperture of moderate size, the outer lip simple, acute, not thickened or reflected, rarely slightly expanded; pillar smooth, the inside of the outer lip not lirated or denticulate; canal varying in length, usually so, sometimes tortuous or, when short, recurved; operculum filling the aperture. Type *Murex islandicus* Gmelin.

*Colus* (*Aulacofusus*) *morditus* Dall, 1919. (Plate 5, fig. 17). Shell small, solid, polished, of about 7 whorls, the apex decorticated, rather acute, the whorls moderately rounded, the suture distinct, not appressed; axial sculpture of feeble incremental lines, their intersections slightly punctating the grooves; spiral sculpture of numerous shallow grooves with much wider flattish interspaces over the whole surface; outer lip thin, sharp, arcuate; inner lip erased, pinkish; pillar white, attenuated in front; canal wide, distinct, short, slightly recurved. Height of shell, 28; of last whorl, 20; of aperture, 15; diameter, 13 mm. (Dall). Station 4198, in Gulf of Georgia, in 200 fathoms, by Dr. C. M. Fraser.\*—Gulf of Georgia.

*Colus* (*Latisipho*) *jordani* Dall, 1913. (Plate 3, fig. 1). Shell of moderate size, of about  $7\frac{1}{2}$  whorls, the nucleus rounded, not swollen but rather large; suture distinct, the whorls moderately rounded; surface covered with a dark orange-brown periostracum, beneath which the shell substance is white; sculpture of incremental lines, not prominent but regular and close set, crossed by numerous flat spirals with very narrow interspaces, this sculpture covering the whole surface, the spirals being slightly narrower in front of the suture; on the

periphery of the last whorl there are about 2 spirals with their interspaces in the width of one millimeter; aperture less than half the length of the shell; canal wide, short, sharply recurved; outer lip simple, flexuous, expanded, receding behind the periphery and advancing near the suture, connected over the body with the pillar by a thin layer of white callus; pillar short, attenuated in front; throat smooth, bluish white; operculum ovate, with apical nucleus, dark brown. Height of shell, 43; of last whorl, 31; of aperture, 20; maximum diameter, 21 mm. (Dall). Off Matia Island, Wash., in 25-35 fathoms.\*—Bering Sea to Puget Sound; off Monterey Bay, Calif., in 633 fathoms.

CHRYSODOMUS Swainson, 1840

Shell large, short-fusiform, smooth or spirally sculptured, sometimes with rude axial ribbing or nodosities; outer coat of the shell subtranslucent, with a darker tint than the inner layers and with the periostracum inconspicuous; last whorl longer than the spire, with a wide aperture, the outer lip flaring or subreflected; pillar flexuous, smooth; body without callosities or lirae; the canal rather long, wide, flexuous; the peptic shell with a rounded, irregular, submamillary nucleus and rapidly increasing subsequent whorls. (Proc. U. S. Nat. Mus., vol. 54). Type *C. antiqua* Linne.

*Chrysodomus tabulatus* Baird, 1863. (Plate 18, fig. 4). Shell large, fusiform; spire elevated; apex subacute; whorls 8, sharply angulated and keeled above, forming a rimmed, spiral table; surface ornamented with revolving ridges of alternating size; suture very deeply impressed; aperture pyriform; outer lip thin, smooth; inner lip incrustated; canal long, narrow, curved backwards; columella twisted, spirally ridged. Length 116, diameter 46 mm. Off San Juan Island, Wash., and general, in 25-30 fathoms.\*—B. C. to San Diego, Calif.

*Chrysodomus liratus* Martyn, 1784. (Plate 48, figs. 1, 2. See also plate 49, figs. 1-4). Shell light brown, encircled on the body-whorl by 9 to 15 revolving ribs, which are not flattened on the top, usually 3 of these ribs are visible on the spire whorls. (Tryon Manual Conch.) Shell with posterior part of whorl rounded, making a smaller angle with the suture; often with more or less strong ribs above the first prominent rib. Ribs slender, more equal, less elevated, not flattened on top; interspaces not channelled, strongly grooved, often with quite prominent intercalated ribs. Aperture purple or livid; if partly white, the white is in the channels corresponding to the ribs, with the interspaces purple. Siphonal fasciole long and

slender, usually nearly obsolete, sometimes quite so. Canal curved more or less strongly to the left of the aperture. Outer margin lighter than the throat. (Dall). Length 75-150 mm. Griffin Bay, San Juan Island, Wash., in 25-35 fathoms.\*—Icy Cape, Arctic Ocean, to Puget Sound; off Point Pinos, Calif., in 958 fathoms; Japan.

SEARLESIA Harmer, 1915. (Euthria)

Nucleus (of *S. dira*) smooth, of 2 laxly coiled smooth whorls changing abruptly into the adult sculpture of a few strong axial ribs crossed by numerous spiral threads. The shell-structure subtranslucent, dark colored; the shell short-fusiform, periostracum inconspicuous; aperture shorter than the spire, the outer lip thickened and internally liriate; the body callous, with a narrow chink between the reflected enamel and the strong siphonal fasciole; canal short, open, slightly recurved. (Proc. U. S. Nat. Mus. Vol. 54). Type *Trophon costifer* S. Wood.

*Searlesia dira* Reeve, 1846. (Plate 44, fig. 10). Shell fusiform, slightly recurved at the base; whorls rounded, encircled throughout with conspicuous elevated rough striae; interior of the aperture grooved; dull brown within and without. (Reeve). Length 50, diameter 23 mm. San Juan Island, Wash., along shore; general.\*—Chirikoff Island, Alaska, to Monterey, Calif.

### Family BUCCINIDAE

BUCCINUM Linne, 1758

Shell ovate or oblong, covered with a horny epidermis; spire elevated, apex acute; aperture large, oval, emarginate in front; canal wide, very short, or a mere oblique truncation of the base of the aperture; columella smooth; inner lip expanded; outer lip usually thin, smooth internally. Operculum ovate, nucleus small, near the outer front edge. (Tryon S. S. Conch.) Type *B. undatum* Linne.

*Buccinum glaciale* Linne, 1761. (Pl. 76, fig. 345, Tryon & Pilsbry's Manual Conch., vol. 3). Shell subulately ovate, sutures of the spire deep, whorls somewhat flattened, longitudinally obliquely plicated, transversely 2-3-keeled, interstices between the keels regularly elevately striated; aperture short, lip conspicuously effused; dull yellowish brown, lip white. Length, 2-3 inches. (Conch. Iconica). Strait of Fuca.—Arctic Ocean to Strait of Fuca; circumboreal.

*Buccinum plectrum* Stimpson, 1865. (Plate 8, fig. 4). Shell rather large and thin, elongated; spire produced; sutures less deep than in *B. tenue*; whorls 7 or 8, regularly convex or slightly appressed,

less gibbous or shouldered at the sutures than in *B. tenuis*, and not carinated. Longitudinal folds very numerous, about 19, as broad as their interspaces, and most prominent near the suture; they are curved in a somewhat sigmoid form, and are sometimes, though rarely, interrupted, or have an intervening fold about the middle of the whorl. The striation of the surface has considerable resemblance to that of *B. glaciale*, the primary grooves being deep cut, with the intervening ridges depressed. But the grooving is far less regular than in that species; the primary grooves are more crowded near the suture, and the ridges less flattened. The secondary grooves on the surface of the primary ridges, are usually as fine as in *B. glaciale*, but often one or more of them becomes deeper, making the sculpture resemble more that of *angulosum*. Aperture oval, less than half the length of the shell, and narrower than in *B. tenuis*. The columella does not project beyond the level of the anterior of the outer lip, but rather falls short. The columella shows the usual 3 folds, but the middle fold being nearly longitudinal and parallel to the lowermost fold, the latter cannot be seen in a front view, but it is easily seen in an edge view of the columella (in broken specimens of the shell), separated from the marginal middle fold by a longitudinal sulcus. The first and second (uppermost and middle) folds are separated by a broad deep sinus. Periostracum thin, smooth, not ciliated. Length, 2.23; breadth, 1.2 inches. Off entrance to East Sound, Wash., in 25 fathoms.\*—Arctic Ocean to Puget Sound; circumboreal.

*Buccinum tenuis* Gray, 1839. (Pl. 36, fig. 19, Beechey's Voyage to the Pacific and Behring's Straits, Zool.) Shell fusiformly ovate, thin, spire rather acuminate; whorls somewhat round, smooth or very minutely spirally striated, concentrically plicately ribbed, lip thin, dead white. Length 1.75-2.5 inches. (Conch. Iconica). Strait of Fuca.—Arctic Ocean to Strait of Fuca; circumboreal.

*Buccinum baeri morchianum* Fischer, 1858. (Pl. 10, fig. 2, Journ. de Conchyl). Shell thin, whorls about 5, suture narrow and deep; shell a little roughened by the growth lines. Color reddish varying to yellowish. In some of the specimens the spiral lines are quite prominent. The spire is high and of a purple color. Length 26 mm. Vancouver Island, by Rev. G. W. Taylor.\*—Bering Sea to Vancouver Island; Kuril Islands.

#### VOLUTHARPA Fischer, 1856

Shell ventricose, thin; spire short, body-whorl and aperture very large. Operculum usually wanting; when present, at first with apical nucleus, afterwards becoming annular. (Tryon Manual Conch.)

*Volutharpa ampullacea* Middendorff, 1848. (Pl. 17, figs. 1-3, Middendorff's Sibirische Reise). Shell reddish brown under a rufous or yellowish epidermis. (Tryon Manual Conch.) Aperture two-thirds the length of the shell, and wider at the base; columella arched; canal wide; epidermis thin, yellowish; suture canaliculated. Length 25 mm. Alert Bay, B. C., by Rev. G. W. Taylor.\*—Bering Sea to Strait of Fuca.

### Family ALECTRIONIDAE

#### ALECTRION Montfort, 1810

Spire elevated, whorls glabrous, polished or papillary; inner lip spreading; outer lip denticulate, not variced externally. (Tryon S. S. Conch.)

*Alectrion fossatus* Gould, 1849. (Plate 22, figs. 3, 4). Shell broad-ovate, elongated, thin livid, ash-coloured, encircled throughout with raised ridges of a deeper colour, interspaces of about equal width. On the upper whorls these ridges are formed into coarse granules by longitudinal folds about equally distant, but more shallow. On the upper slope of the last whorl, in some specimens, these are increased so as to become conspicuous, very oblique waves or nodules, terminating at the middle of the whorl. Spire of 7 convex whorls, the last of which is ventricose, and has the usually constricted, posterior groove encircling the beak excavated into a broad, remarkably deep canal; suture linear. Aperture broad, quadrate-ovate; lip sharp, simple, oblique posteriorly, parallel to the axis laterally and perpendicular to it at base, thus forming an obtuse angle at the posterior third, and a right angle at its anterior limit, which is a little in advance of the point of the beak; siphonal notch broad, short, scarcely reflected; pillar covered with a thin layer of enamel, but in general not enough to obliterate the groove and ridges, so that it appears corrugated throughout. In old specimens the callus rises into an elevated marginal wall, with oblique folds and a canal at the angle posteriorly; interior of the aperture with sharp, raised revolving lines. Length,  $1\frac{1}{4}$ ; breadth,  $\frac{3}{4}$  of an inch. (Gould). Port Crescent, Wash.—Vancouver Island to Cerros Island, Lower California.

*Alectrion mendicus* Gould, 1849. (Plate 22, fig. 6). Shell small, rather light, elongated, ovate-turreted, dull brown, becoming ash-colored when dry, longitudinally undate-plicate, spirally encircled with raised threads, with equal interspaces, about 7 on the penultimate whorl, the depressed portions darker than the raised. Spire elongate-conic, this form being continued nearly to the base. Whorls 6 or 7,



convex, the last a little more than half the length of the shell, ellipsoidal; constriction around the siphonal canal well-impressed; this groove broad, short, a little reflexed and somewhat contorted. Aperture small, not more than one-third the length of the shell, rounded-ovate; lip sharp and simple, having a series of about 10 laminae within, not reaching the edge: pillar strongly arched, smooth, slightly invested with an ivory callus, the point projecting as far as the lip does anteriorly; fauces white, the siphonal notch tinted salmon-colored. (Gould). Length 20, diameter 10 mm. Off San Juan Island, Wash., in 15 fathoms; also several stations off Vancouver Island.\*—Kodiak Island, Alaska, to Magdalena Bay, Lower California.

*Alectrion cooperi* Forbes, 1850. (Pl. 11, fig. 4, Proc. Zool. Soc., 1850). This is typically very distinct, with its 7 or 8 distinct, prominent, shouldered ribs, but specimens are not rare which, commencing with the numerous ribs of *A. mendicus*, suppress alternate ones and increase the prominence of those remaining on the body-whorl. There are also specimens intermediate in form and number of longitudinal ribs, and even some in which the ribs are obsolete on the body-whorl. (Tryon Manual Conch). I give the original of Forbes' description:

"N. testa lanceolata, turrita, crassa, anfractibus 6, convexiusculis, spiraliter sulcato-straitis, longitudinaliter 8-costis distantibus, fortibus, distinctis; anfractu ultimo  $\frac{1}{2}$  longitudinis testae aequante, apertura ovata, canali brevi; abro externo crasso, simplici; labro columellari reflexo, albo; cauda alba; anfractibus fuscis, obscure albo-fasciatis." (Forbes). Length 20-23 mm. Puget Sound.\*—Puget Sound to San Diego, Calif.

*Alectrion perpinguis* Hinds, 1844. (Plate 22, fig. 5). Shell small, conical; spire elevated; apex subacute; whorls 7, convex, abruptly truncated at posterior margin, forming a spiral table; ornamentation consists of sharp, spiral ridges with slightly wider interspaces, and posteriorly sloping transverse ridges, the whole giving a decidedly cancellate appearance to the surface; suture deeply impressed, distinct; aperture subovate; inner portion of aperture ridged by spiral sculpture; outer lip thin; inner lip thinly incrustated; columella twisted and spirally ornamented; groove on upper part of columella prominent; canal short, curved. (Arnold). Length 23; height 12.3; body-whorl 15; aperture, including canal, 11 mm. Puget Sound.—Puget Sound to Cerros Island, Lower California.

**Family COLUMBELLIDAE****COLUMBELLA Lamarck, 1799**

Shell strombiform or obovate, smooth or longitudinally or transversely ribbed; internal lip excavated in the middle, crenulated or denticulated in front; outer lip inflected and internally thickened and crenulated in the middle. (Tryon S. S. Conch.)

*Columbella* (*Alia*) *tuberosa* Carpenter, 1865. (Pl. 50, figs. 40, 41, Tryon & Pilsbry's Manual Conch., vol. 5). Shell smooth; whorls 6, rather flat, the body whorl having an obtusely angulated periphery; nucleus white and smooth, flat on top, not swollen. Length 7-8 mm. (Tryon Manual Conch.) Puget Sound.—Forrester Island, Alaska, to San Diego, Calif.

*Columbella gausapata* Gould, 1850. (Pl. 19, fig. 337, Gould's Mollusca and Shells of U. S. Explor. Exped., 1852;—under Wilkes). Shell small, solid, ovate-turreted, elongated, without striation except a few lines around the beak, smooth, polished, covered with a dense russet-colored epidermis having indistinct, paler maculations beneath. Whorls 6 or 7, nearly flat, the last less than two-thirds the whole length, abruptly sloping to the beak, which is short; suture linear, abrupt, deeply impressed; aperture one-third the length the shell, narrow-lunate; lip simple, with a few rib teeth within, both margins deep purplish-brown; callus on the pillar not abundant; interior pale-lilac. (Gould). Length 13, diameter 5 mm. San Juan Island, Wash.; Departure Bay, B. C.\*—Port Etches, Alaska, to San Diego, Calif.

*Columbella carinata californica* Gaskoin, 1852. (Pl. 10, fig. 9, Arnold's Palaeont. San Pedro). Shell oblong-ovate, smooth and shining, rather pyramidal, of a brown color, varying much in intensity and markings, in being sometimes uniform, in others with 1 or 2 thin darker coloured cinctures, or with a broad and continuous dark irregular markings spirally passing on the whorls to be lost in the deeper colour of the apicine volutions; spire acuminate, about half the length of the shell; volutions 7, convex; aperture wide, subquad-rangular; outer lip rather thin, denticulated within on its whole extent; inner lip slightly denticulated along its rather angular inner edge; fine striae traverse the anterior part of the dorsum; peritreme of a dark purple-brown color; channel very short. Length, 40/100 of an inch; width, 20/100 of an inch. (Gaskoin). Off San Juan Island, Wash.\*—Forrester Island, Alaska, to Selina Cruz, Mex.

*Columbella* (*Astiris*) *hypodra* Dall, 1916. (*Columbella variegata*

Stearns, 1871). (Pl. 1, fig. 5, Proc. Calif. Acad. Sci., vol. 5; also pl. 6, fig. 10, Bull. U. S. Nat. Mus., No. 112). Shell small, elongated, acutely conic, light rufous-brown or sienna-yellow under a thin brownish or greenish epidermis; with reddish median and sutural bands more or less interrupted; in some specimens these bands are connected by waved lines of a darker brown; surface of shell when free from epidermis smooth and shining, marked with delicate incremental lines, and on the lower portion of the body whorl with narrow grooves; apex rounded, whorls 7, convex; suture well defined, aperture ovate, about one-third the length of the shell; outer lip simple, in some specimens a little thickened with small tubercles on the inner side. Long. 0.3; lat. 0.12 of an inch. (Stearns).—Puget Sound to Puerto Libertad, Mex.

NITIDELLA Swainson, 1840

Shell oval, smooth, spire elevated; aperture somewhat effuse below; columella with two small anterior plications, outer lip somewhat thickened. (Tryon S. S. Conch.)

*Nitidella gouldii* Carpenter, 1857. (*N. dalli* E. A. Smith). Shell fusiformly ovate, yellowish white, reticulated with pale brown, the interstices being of irregular shapes and sizes or in other words, it is pale brown, closely spotted irregularly with yellowish white; epidermis very thin; apex eroded, remaining whorls 6, flattish or scarcely convex, smooth, separated by a deep suture, giving the spire a slightly turreted aspect; last whorl feebly angular at the middle, contracted inferiorly, and striated around the extremity; aperture pale lilac within, occupying about three-sevenths of the entire length; outer lip arcuate, thickened, especially at the upper part; thin at the margin, and armed within the mouth with about 7 elongated tubercles; columella arched above, oblique at the base, with indications of 1 or 2 tubercles below the middle, covered with a thin whitish callosity; basal canal a little recurved. (E. A. Smith). Carpenter's description of *N. gouldii* is merely "Slender: like thin *A. gausapata*, with a purpuroid operculum." Length 14, diameter 5.33. Off San Juan Island, Wash., in 25 fathoms.\*—Vancouver Island to Puget Sound.

AMPHISSA H. & A. Adams, 1853

Shell bucciniform, longitudinally ribbed; spire elevated; aperture rather wide, enlarging below, and terminating in a wide anterior sinus; inner lip callous, plicate below; outer lip not thickened on margin, plicate within.

*Amphissa columbiana* Dall, 1911. (*A. corrugata* Reeve, 1845). (Pl. 16, fig. 9, Amer. Journ. Conch., vol. 7; also pl. 6, fig. 9; and pl. 11, fig. 9, Bull. U. S. Nat. Mus., No. 112). Shell oblong-ovate, whorls transversely striated, striae stronger toward the base, obliquely wrinkled round the upper part; light bay color. (Conch. Iconica). Length 31, diameter 14 mm. San Juan Island, Wash., and general; shore.\*—Chiachi Island, Alaska, to Calif.

### Family MURICIDAE

PURPURA Martyn, 1784. (Cerostoma)

Shell triangular, varices wing-like; aperture elongate-ovate. Canal moderately long, usually closed in adult specimens; outer lip with a produced tooth near to the base. Type *P. nuttalli* Conrad.

*Purpura foliata* Martyn, 1784. (Plate 20, fig. 11). Shell ovately oblong, spire rather short; whorls transversely ribbed, ribs small, compressed, somewhat distant, interstices smooth; 3-varicose; varices thin, erectly foliated whitish, banded with chestnut brown; aperture small, columella lip simple, outer lip denticulated, armed at the lower part with a small flattened tooth; canal short, flatly compressed, closed. (Conch. Iconica). Length 85, diameter 45 mm. San Juan Island and Olga on Orcas Island, Wash.; shore and dredged.\*—Sitka, Alaska, to San Diego, Calif.

TRITONALIA Fleming, 1828. (Ocinebra Leach).

Spire elevated; varices numerous, rounded, sometimes raised; canal generally closed. (H. & A. Adams, for *Ocinebra*). Fleming did not describe this genus *Tritonalia*, but did designate, as the type, *T. crinacea* Linne.

*Tritonalia lurida* Middendorff, 1849. (Pl. 4, figs. 4, 5, Middendorff's Beitrage zu einer Malacologia Rossica; also pl. 20, fig. 7, Proc. U. S. Nat. Mus., vol. 15). Shell fusiform, spire elongated, canal short, open; whorls closely asperately lirate, the lirae crossing a few rounded ribs; aperture dentate within. Color reddish or chocolate. Length 29, diameter 13 mm. (Tryon Manual Conch.) Rocky Point and False Bay, San Juan Island, Wash.; shore.\*—Forrester Island, Alaska, to Catalina Island, Calif.

*Tritonalia lurida aspera* Baird, 1863. (Plate 20, fig. 8). Shell of medium size, fusiform; whorls 6, convex, with about 9 prominent, rounded transverse ribs; surface ornamented with numerous rounded,

raised, spiral lines and fine incremental lirulae in the interspaces; sutures deeply impressed, distinct; body-whorl prominently ventricose, and with transverse, rounded ridges which become obsolete on columella; aperture subovate; outer lip thickened, denticulated; inner lip slightly flattened, incrustated; columella only slightly widened; umbilicous subperforate; canal straight, narrow. (Arnold). Length 27, height 14 mm. Puget Sound?—Sitka, Alaska, to San Pedro, Calif.

*Tritonalia lurida munda* Carpenter, 1864. (Pl. 20, fig. 13, Proc. U. S. Nat. Mus., vol. 15). Shell small, fusiform, thick, solid; spire elevated, apex acute; whorls 5 or 6, evenly convex; sculpture consists of rather low, rounded, transverse ridges (of which there are about 12 on the penultimate whorl) and equal, equidistant, rounded, raised, spiral lines (of which there are 6 on the penultimate whorl); suture quite deeply impressed; aperture elliptical; outer lip thickened with row of denticles interiorly; inner lip and columella smooth; canal short, narrow, generally covered. (Arnold). Length 14, height 6.5 mm. Puget Sound?—Middleton Island, Alaska, to San Diego, Calif.

*Tritonalia sclera* Dall, 1919. Shell of moderate size, yellowish, flushed with more or less dark brown, with 6 well-rounded whorls exclusive of the (lost) nucleus; suture obscure, undulated; axial sculpture of (on the last whorl 8, on the penultimate whorl 10) low inconspicuous rounded ribs extending more or less distinctly to the canal with continually wider interspaces; also low sharp incremental lines minutely imbricating the whole sculpture; spiral sculpture of (on the penultimate whorl about 7, on the last whorl about 25) strong prominent cords with wider interspaces usually showing an intercalary thread which on the last whorl becomes nearly as strong as the others; aperture rounded, outer lip simple, periodically varicose; body erased, pillar straight; canal distinct, open, narrow, slightly recurved. Height of shell, 29; of last whorl, 21.5; of aperture and canal, 15; diam., 16 mm. (Dall). Near Port Townsend, Wash., in 20 fathoms.—Puget Sound to Venice, Calif.

*Tritonalia interfossa* Carpenter, 1864. (Plate 5, fig. 5). Shell narrower and more shouldered than the last species, the lattice of revolving lirae and longitudinal ribs coarser and more elevated; canal short and closed. Length, 24; diameter, 12 mm. (Tryon Manual Conch.) False Bay, San Juan Island, Wash.\*—Semidi Islands, Alaska, to San Diego, Calif.

*Tritonalia interfossa atropurpurea* (Carpenter.) Dall, 1919. This

form resembles *clathrata*, but is more elongated and much less distinctly turritid. The color when fresh is a purplish black, which, however fades in the cabinet to a more or less ruddy brown, after some years. Carpenter's MS. name. Height, 19; diameter, 7 mm. (Dall). Neah Bay, Wash.—Neah Bay, Wash., to San Diego, Calif.

*Tritonalia fraseri* I. Oldroyd, 1920. (Plate 9, figs. 1, 2). Shell of medium size, very elongate, narrow; whorls including the nucleus, which is present on nearly all the specimens collected, 7; suture distinct and deep, whorls strongly shouldered, with 6 strong ribs, spinose at the shoulder; body whorl with 9 strong spiral cords and with incremental ones between. The shoulder is very strongly rugose, and has from 1 to 2 spiral cords; the second whorl, has 4 strong spiral cords and 3 incremental ones; the third has 3 strong spiral cords and no incremental ones. Aperture elongate-oval, interior yellowish to purple-brown, columella thickened and nearly straight, canal long, straight and closed in the adult. It differs from the typical form of *T. interfossa*, in the very elongate form, and the absence of the basket-like sculpture. In some specimens on the fifth and sixth whorl the basket sculpture shows faintly. Length 20, diameter 9 mm. Branden Island, Departure Bay, Vancouver Island.\*—Vancouver Island.

*Tritonalia barbarensis* Gabb, 1866. (Plate 20, fig. 9). Shell small, brown; whorls 6, the first smooth, the remainder angulated, horizontally or a little concavely truncated above and very slightly convex below the angle; varices variable, from 5 to 9, usually about 6 or 7 to a whorl, angular but not very prominent, except on the angle, where they are sometimes prolonged into long recurved processes, in other cases only making a prominent angular tubercle; the whole surface is covered with strong revolving ribs, crossed by fine squamose plates; aperture sub-elliptical, lips prominent, white within, the outer lip with 5 or 6 tubercles internally, last verix forming a broad lateral expansion to the lip; canal closed, straight, or more usually a little recurved. (Gabb). Length 20-25 mm.—B. C. to San Pedro, Calif.

*Tritonalia michaeli* Ford, 1888. Shell fusiform, rather slender, turritid, light gray, with a narrow median brown band; whorls 5, convex, shouldered above, the upper ones carinate; sculptured with numerous rather coarse revolving lirations, the interstices with riblets bearing crowded festooned lamellae of growth, which are also prominent below the sutures; longitudinally prominently plicate, with about 7 folds to each whorl; aperture oval, white within, angular above; anterior canal quite long, open, straight; outer lip thickened

within, bearing 6 small tubercles; columella nearly straight; with a whitish callus projecting slightly at beginning of canal. (Ford). Length of shell 16, diameter 8, length of aperture 9 mm. Orcas Island, Wash., by C. C. Engberg.—Orcas Island, Wash., to Gulf of California.

*Trophon* Montfort, 1810

Varices numerous, lamelliform or lacinated; spire prominent; aperture ovate; canal open, usually turned to the left; shell white, often dark-colored within the aperture. (Trvon S. S. Conch.) Type *T. clathratus* Linne.

*Trophon* (Neptunea) *macouni* Dall, 1910. (Plate 12, fig. 7). Shell small, dark purple, with the prominences white. Whorls about 6, the nuclear smooth and submamillary; the succeeding whorls with (on the last 9) prominent, thin, sharp varices, sharply angulated at the shoulder; whorls subtabulate, the suture distinct but not deep; sculpture (besides the varices) of 2 to 7 low revolving flat ridges which appear whitish against the purple ground-colour, and numerous fine, spiral, almost microscopic lines often obsolete; besides the angle at the shoulder there are usually 2 of these ridges on the spire behind the last whorl; they hardly modify the verices; aperture small, sub-ovate, with the outer lip somewhat expanded; canal white, rather long and narrow, directed somewhat toward the left. Height of the shell, 13; of last whorl, 9; max. diam., 6 mm. (Dall & Bartsch). Barkley Sound, Vancouver Island.—Port Althorp, Alaska, to Barkley Sound, Vancouver Island.

*Trophon* (Neptunea) *pacificus* Dall, 1902. (Plate 19, fig. 6). Shell dirty-white, ovate-fusiform; canal long, curved. Aperture ovate-elongate; aperture and canal more than half the length of the shell. Whorls 7; sutures moderately deep. Body whorl with about 19 low, sharply rounded varices. Aperture white or tinted with chocolate. Columella curved; outer lip thin at the edge but thickened on inner border. Dall says it is the commonest Pacific coast species and has been called by Dr. Carpenter *Trophon sculariformis* on his labels. Length 25, breadth 12 mm. Friday Harbor, Wash., by C. C. Engberg.—Arctic Ocean to Acapulco, Mex.

*Trophon* (Neptunea) *beringi* Dall, 1902. (Plate 18, fig. 8). Shell greenish white, elegantly ovate-fusiform, with a rather elongated curved canal, the aperture and canal longer than the spire; whorls with the base gradually attenuated, not constricted, about 6 in number, with a distinct but not deep suture and 9 to 12 low sharp round-

ed varices, with no obvious angle at the shoulder; surface with fine revolving striation, sometimes partly obsolete; aperture white. Length 40 mm. (Dall). Puget Sound.—Icy Cape, Arctic Ocean, to Puget Sound; Japan.

*Trophon* (Neptunea) *multicostatus* Eschscholtz, 1829. (*Boreotrophon gracilis*). (Plate 19, fig. 5). Shell small, fusiform; whorls 5, angular above, with 12 to 14 raised varices; no spiral sculpture; aperture subelliptical; outer lip not effuse; inner lip smooth; canal short, slightly curved. (Arnold). Length 10.5, breadth 4.5, body-whorl 7, aperture, including canal, 5 mm. Victoria, B. C.—Nunivak Island, Bering Sea, to San Pedro, Calif; northern Japan.

*Trophon* (Neptunea) *orpheus* Gould, 1849. (Plate 18, fig. 7). Shell minute, fusiform, thin, elongated, tirrited, cinereous, with numerous longitudinal, lamellar, sharp, muricated ridges, 13 on the last whorl, angular near the suture, crossed by rounded, raised threads of considerable size, which commence gradually in front of a rib, and terminate on the succeeding one, 2 or 3 on the upper whorl, 5 or 6 on the last, neither set continued upon the beak. Whorls 6, with a broad shoulder near the suture, angular, the last two-thirds the length the shell, ventricose above, the lower half terminating in a slender beak, a little recurved. Aperture half the length of the shell, elliptical; lip angular posteriorly, a little everted, sharp and simple; pillar with a slight intrusion at the commencement of the canal; interior pale flesh-colour. Length half an inch; breadth one-fifth of an inch. (Gould). Off San Juan Island and at East Sound, Wash.; Departure Bay, B. C.\*—Victoria, B. C., to off the Columbia River, Ore.

*Trophon* (Neptunea) *stuarti* E. A. Smith, 1880. (Plate 8, fig. 1). "Testa breviter fusiformis, alba. Anfractus 7, superne planati et angulati lateribus planis, costis late lamelliformibus, aliquanto obliquis, erectis, superne ad angulum valde sursum productis dextrorsumque curvatis, costis, transversis (in anfr. superioribus 2-3, in ultimo 4) aequidistantibus, et supra longitudinalibus continuis instructi. Apertura irregulariter ovata, inferne in canalem producta. Canalis curvatus, retrorsus, aperturam fere aequans. Columella leviter arcuata, callo tenui exus libero indutu. Labrum expansum, costa ultima lamelliformi extus munitum." (E. A. Smith). Length 53, diameter 21 mm. Off Lopez Island, Wash., in 25-30 fathoms.\*—Shumagin Islands, Alaska, to San Diego, California.

This is a pure white shell, remarkable on account of the thin lamellae which adorn it. At the upper part, at the angle of the whorls, these are much prolonged upwards, hollow on one side, ridged



on the other, and curved to the right. Of the spiral lirae, that at the angle is rather stouter than the rest. Upon the upper whorls they are proportionally more elevated than upon the last, and, with the longitudinal lamellae, form a coarse reticulation. Upon the body-whorl toward the lower part, they cease to be erect, are lapped one upon another, and form an imbricated caudal ridge subparallel with the canal. The entire surface is both spirally and longitudinally minutely striated, a feature observable only under a lens. (E. A. Smith).

*Trophon* (Neptunea) *tenuisculptus* Carpenter, 1866. (Plate 8, fig. 2). Shell small, fusiform; whorls 5, angulated above, forming a slightly sloping, tabular band above; ornamentations of numerous transverse ridges and several spiral lines; suture deeply impressed; aperture elliptical; outer lip thin; inner lip incrustated, smooth; canal narrow; columella long, twisted. (Arnold). Length 40, breadth 14 mm. Off San Juan and O'Neal Islands, Wash.; off Departure Bay, B. C.\*—Southeastern Bering Sea to Todos Santos Bay, Lower California.

THAIS Bolten, 1798. (In part *Purpura* Lamarck)

Bolten did not describe his genus *Thais*. He gave as first species, *Purpura neritoides* Lamarck. We do not have any true *Thais* in the north, ours belong to the subgenus *Nucella* Bolten, 1798; and may be described as: Last whorl large; spire in some species short, in others long; aperture ovate, about half the length of the shell; outer lip thickened, toothed within in most species; surface with coarse revolving ridges and sometimes with fine frills, which mark the lines of growth.

*Thais* (*Nucella*) *lamellosa* Gmelin, 1792. (*Purpura crispata*). (Plate 14, figs. 1, 2, 4; plate 43). Shell fusiform, thick; spire elevated; apex subacute; whorls 5 to 7, convex or angulated, with 1 or more prominent spiral ridges on angular part of whorl; suture impressed, distinct; aperture ovate to elliptical; outer lip effuse, generally denticulate; inner lip incrustated, smooth; canal short, curved backwards; umbilicus subperforate. Length 80, diameter 40 mm. General on the islands of Puget Sound; dredged in 25-30 fathoms off Shaw and San Juan Islands.\*—Bering Strait to San Francisco, Calif., and Japan.

*Thais* (*Nucella*) *lamellosa hormica* Dall, 1915. (Plate 14, figs. 3, 5). Shell of smaller size, thin, with spire subacute, produced, longer than the aperture; whorls angular with more or less prominent

axial laminae, 10 or more to the last whorl, often produced at the angles into guttered spines; major spirals 2 on the penultimate, 5 or 6 on the last whorl; aperture small, the outer lip hardly expanded, only moderately callous; the umbilical chink usually obsolete. Length, 64; diameter, 26 mm. (Dall). Off San Juan Island, Wash., and Jessie Island, Departure Bay, B. C.\*—Sitka Harbor, Alaska, to Puget Sound.

*Thais* (*Nucella*) *lamellosa cynica* Dall, 1915. (Plate 22, fig. 11). Shell short, robust, heavy, very thick, spire short-conic, shorter than the aperture, one mutation being sparsely laminate, the other with a smooth surface; whorls flattened behind the shoulder; major spirals obsolete or none; when present, there is one on the penultimate whorl and 5 or 6 on the last whorl; aperture large, outer lip flaring, umbilical chink usually concealed by callus. Length, 43; diameter, 26 mm. (Dall). Lopez Island, Wash.; shore.\*—Puget Sound to San Francisco, Calif.

*Thais* (*Nucella*) *lima* Martyn, 1784. (Plate 22, fig. 13). Shell of  $3\frac{1}{2}$  rounded whorls, not including the nucleus; moderately thick with a spire much shorter than the aperture, the last whorl much the largest; with a tolerably uniform spiral sculpture of alternated major and minor spiral cords; aperture large; outer lip not reflected and seldom thickened, more or less crenulated by the sculpture; pillar slightly arcuate, flattened anteriorly, the canal narrow and curved to the left; umbilicus sometimes sealed, at others showing a deep narrow perforation behind the callus of the reflected pillar. (Dall). Height of shell 43, height of last whorl 40, breadth 30 mm. Vancouver Island, by Rev. G. W. Taylor.\*—Kotzebue Sound, Arctic Ocean, to Lower California and Japan.

*Thais* (*Nucella*) *canaliculata* Duclos, 1832. (Plate 22, fig. 9; plate 3, figs. 12, 13). Shell bucciniform, of  $3\frac{1}{2}$  to 4 rounded whorls exclusive of the nucleus, moderately thick, with a spire about half shorter than the aperture, the last whorl largest, with a very uniform sculpture, of strong elevated spiral ridges separated by distinctly channeled interspaces crossed by small slightly elevated axial lamellae or elevated lines; minor spirals very rarely occur; there are 4 to 6 major spirals on the penultimate whorl and about 10 on the last whorl; outer lip not reflected and only slightly thickened, usually crenulated by the external sculpture; pillar moderately arcuate, flattened in front where the callus conceals but does not seal a long narrow umbilical chink; canal narrow, recurved. Height, 41; breadth,

23 mm. (Dall). San Juan Island, Wash.; shore, general.\*—Aleutian Islands to Monterey, Calif.

*Thais* (*Nucella*) *emarginata* Deshayes, 1839. (Pl. 25, Guerin's Mag. de Zool., 1841). Shell ovate, thick, spire short, whorls obliquely plaited and wrinkled, transversely ribbed; ribs rugose, compressed, sharply noded; columella excavated, largely dilated; reddish-brown, interior of the aperture brown, lip and columella whitish. (Conch. Iconica). Height 34, breadth 23 mm. San Juan Island, Wash., and general.\*—Bering Sea to Mazatlan, Mex.

*Purpura saxicola* is identical with *Thais emarginata*.

*Thais* (*Nucella*) *emarginata projecta* Dall, 1915. (Plate 15, fig. 4, 5). Shell thinner, more elongate and with a pointed spire, the major and minor spirals more nearly equal, 2 strong spirals on the earlier whorls and the sutures more constricted. Height, 31; breadth, 17 mm. (Dall). Olga, Orcas Island, Wash.\*—Alaska to Puget Sound.

### Family CORALLIOPHILIDAE

CORALLIOPHILA H. & A. Adams, 1853

Shell broadly fusiform; nuclear whorls smooth; postnuclear whorls with rasp-like surface, and somewhat open umbilicus. (Arnold).

*Coralliophila* (*Pseudomurex*) *kincaidi* Dall, 1919. Shell fusiform, dirty white, with about 6 shouldered whorls, the nucleus decorticated, the suture deep, very narrow; axial sculpture of 9 rather sharp vertical ribs extending from the suture to the canal with wider interspaces; spiral sculpture of (on the penultimate whorl 8) strong subequal cords, with narrower deep interspaces covering the whole shell, all furnished densely with short guttered lamination as usual in the genus; aperture ovate, outer lip simple, fringed by the external sculpture, inner lip glazed with white enamel; canal rather long, bent to the left, narrow, open, with a strong laminose fasciole. Height of shell, 30; of last whorl, 21; diameter, 15 mm. (Dall).—Known only from Puget Sound.

### Family EPITONIDAE

EPITONIUM Bolten, 1798. (*Scalaria* Lamarck, 1801; Scala)

Shell mostly pure white and lustrous, umbilicated or imperforate; spire elongated, the apex more or less inflected; whorls numerous, rounded, in contact or separated, ornamented with longitudinal ribs

or thin lamellae, often continuous across the suture; peristome entire, thickened, reflected. (Tryon Manual Conch.) Bolten did not describe his genus *Epitonium*, but gave *E. scalaria* Linne as the type.

*Epitonium* (Nitidoscala) *indianorum* Carpenter, 1865. (Pl. 14, fig. 48, Tryon & Pilsbry's Manual Conch., vol. 9). Shell thick elongated; spire elevated; apex acute; whorls 10, rounded, with 12 to 16 heavy, reflexed varices; varices striated with fine incremental lines; suture deep; aperture subcircular; inner lip thickened, forming columella. Length, 26; diameter, 9 mm. (Arnold). Off San Juan Island, Wash., in 20-25 fathoms.\*—Forrester Island, Alaska, to Todos Santos Bay, Lower California.

*Epitonium* (Nitidoscala) *subcoronatum* Carpenter, 1866. *Scalaria* with compact shell, little elevated, white; 10 rotund whorls scarcely touching; ribs about 13, very sharp, expanded, little reflexed, touching the rear, ascending the spire in a line parallel to the right margin of the spire. Adolescent shell scarcely coronate in the rear on the adult shell, simple. Aperture subcircular, no umbilicus, no spiral sculpture. (A free translation). Long. 0.45 inch. Vancouver Island.—Vancouver Island to San Diego, Calif.

*Epitonium* (Nitidoscala) *caamanoi* Dall & Bartsch, 1910. (Plate 12, fig. 1). Shell small, rather conic, white, with 13 broadly reflexed, axially conspicuously striated varices; nucleus? (lost); whorls more than 6, varices continuous up the spire, narrow near the suture, more than doubling in width at the shoulder, where they are provided with a small spine or prominent angulation, then continuing to the base, where they are again narrowly contracted; there is no basal cord or disk, the umbilicus is closed; the surface of the whorls between the varices is smooth; the whorls are evenly rounded, and the aperture, if perfect, would probably be nearly circular. Length of 6 whorls (decollate), 9.5; diameter at base, 5, at decollation, 0.7; of aperture, 2 mm. (Dall & Bartsch). Barkley Sound, Vancouver Island.—Vancouver Island to San Pedro, Calif.

*Epitonium* (Nitidoscala) *densiclathratum* Dall, 1917. Shell white, solid, with 6 or 8 well-rounded whorls exclusive of the (lost) nucleus; varices 10 or 11, sharply axially grooved on their anterior faces, solid, thick, not continuous over the suture, on the base showing a slight flattening, though there is no basal cord or disk; aperture ovate; behind the inner margin there is a narrow flattened area reflected over the umbilical region in the type specimen. Length, 17; diameter, 7.5 mm. (Dall). Puget Sound.—Puget Sound to San Diego, Calif.

*Epitonium crebricostatum* Carpenter, 1866. Shell turritid, thin; spire consists of 8 convex whorls, each with 14-18 slightly oblique, sharp, thin, reflexed, transverse varices; varices show a slightly coronate appearance at the shoulder; suture deep and distinct. (Arnold). Vancouver Island.—Vancouver Island to Gulf of California.

*Epitonium* (*Opalia*) *wroblewskii* Moersch, 1876. (*Opalia borealis* Lyell). (Plate 5, fig. 11; plate 19, fig. 4). Shell solid, bluish white; whorls 12, with (on most specimens) 7 or 8 heavy rounded ribs, the interspaces about twice the width of the ribs. This is the same as *E. boreale* Gould, according to Dall. *E. borealis* (Beck) Lyell, 1839. (Plate 19, fig. 4) is, however, a different species, but is not known south of the Aleutian Islands. Length 50 mm. Griffin Bay, of San Juan Island, Wash., in 40 fathoms.\*—Forrester Island, Alaska, to San Diego, Calif.

### Family MELANELLIDAE

MELANELLA Bowdich, 1822. (Eulima)

This genus as here constituted embraces the white polished mollusks that have the last whorl produced and the inner lip appressed for its entire length, or at least for the greater part of its length, to the attenuated base. The shells may be straight or flexed. (Bartsch). Type *M. dufresnii* Bowdich.

*Melanella micans* Carpenter, 1864. (Plate 5, fig. 6). Shell straight, elongate-conic, bluish-white when the animal has been removed. When the animal has been allowed to dry in the shell, it appears through the substance of the shell and gives it a mottled brownish aspect. The brownish coloration when present usually extends over the upper half of the specimen. Whorls flattened, decidedly appressed at the summit. Sutures appearing as a very fine impressed line. Base moderately long, well rounded. Aperture oval; posterior angle very acute; outer lip thin at the edge, bent back immediately below the summit, then forward to form a claw-shaped element, the center of which coincides with the periphery; there is another backward deflection of the outer lip at its junction with the inner lip which is moderately strong, curved and twisted and partly reflected over and adnate to the base; parietal wall covered with a moderately thick callus. Length 12.5; diameter, 4 mm. (Bartsch). San Juan Island, Wash.; Departure Bay, B. C.\*—Vancouver Island to Point Abreojos, Lower California.

*Melanella micans borealis* Bartsch, 1917. (Plate 35, fig. 7, Proc. U. S. Nat. Mus., vol. 53). From Vancouver Island north we have a

race of *M. micans* which is uniformly more slender than the race to the south. This may have the specific name applied to it above. Length, 11.3; diameter, 3.3 mm. (Bartsch). Comox and Departure Bay, B. C.—Kodiak Island, Alaska, to Vancouver Island.

*Melanella rutila* Carpenter, 1864. (Plate 35, figs. 2, 3, 6. Proc. U. S. Nat. Mus., vol. 53). Shell of medium size, elongate-conic, slender, straight, surface polished, glassy without perceptible sculpture, excepting irregularly distributed varices. Whorls appressed at the summit to such an extent that the suture is scarcely perceptible; the basal portion of the preceding whorls, shining through the substance of the succeeding turns as a false suture; the true suture appearing about one-third of the way between the summit and the false suture above the latter. Periphery of the last whorl rounded, base sloping in such a way as to lend the left outline a somewhat flattened appearance. Aperture large, oval; posterior angle acute; outer lip decidedly protracted between the base and the posterior angle, forming a claw-like extension; inner lip short, moderately stout, somewhat curved, reflected over and appressed to the base; parietal wall covered with a moderately thick callus. Length, 6.8; diameter, 1.9 mm. (Bartsch). Departure Bay, B. C., by Dr. C. M. Fraser.\*—Vancouver Island to Magdalena Bay, Lower California.

*Melanella oldroydi* Bartsch, 1917. (Plate 44, fig. 4). Shell rather broadly elongate-conic, bluish-white in the living form, yellowish-white in the fossil, polished, marked by exceedingly fine lines of growth only. The first 3 whorls well rounded, separated by a moderately impressed suture; the succeeding flattened, separated by a feebly defined suture. Periphery of the last whorl weakly angulated. Base short, well rounded. Aperture oval; posterior angle acute; outer lip angulated at the junction with the basal lip and slightly protracted at the angle; inner lip short, curved, strongly reflected and appressed to the base posteriorly; parietal wall covered with a thick callus. Length, 9.2; diameter, 3 mm. (Bartsch). Inside Dodds Narrows, B. C., in 15 fathoms.\*—Gulf of Georgia to Point Abrejos, Lower California.

*Melanella randolphi* Vanatta, 1899. (Plate 11, figs. 13, 14, Proc. Acad. Nat. Sci. Philadelphia, 1899). Shell smooth, rather slender, shining, bluish-white when empty, but when the animal is dried in, the spire is orange colored above, pink in the middle with sometimes a slight yellowish band on the body whorl; opaque; outlines of the spire straight, conical. Apex blunt, rounded, of moderate size, suture impressed; no varices. Seven or 8 whorls, the body whorl ovate, whorls of the spire a little convex. Aperture ovate, outer lip sloping

to the right, nearly straight, in profile it is moderately arched forward below and sometimes retracted very slightly above. Columella slender, concave below, convex above, forming an angle with the convex parietal wall, parietal callus very thin. Length, 6; diameter, 2.3 mm. (Vanatta).—Unalaska, Alaska, to Puget Sound.

*Melanella tacomaensis* Bartsch, 1917. (Plate 46, fig. 2). Shell small, straight, broadly elongate-conic, bluish-white, except where the animal shines through, there it appears golden brown; surface marked by exceedingly fine lines of growth and almost invisible microscopic spiral striations. Whorls flattened, separated by a scarcely defined suture; the basal portion of the preceding whorl shining through the substance of the succeeding turn appears as a conspicuous false suture. Periphery obscurely angulated; base short, flattened, the left margin very obliquely sloping. Aperture moderately large; posterior angle acute; outer lip very thick within, thin at the edge, decidedly protracted a little anterior to the middle between the posterior angle and the base; inner lip very stout, somewhat flexuous, reflected over and appressed to the base; parietal wall covered with a thick callus. Length, 5; diameter, 2.1 mm. (Bartsch).—Known only from Tacoma, Wash.

*Melanella* (Balcis) *columbiana* Bartsch, 1917 (Plate 44, fig. 1). Shell large, rather stout, polished, with a double flexure; when viewed with the aperture to the front it shows the early whorl bent backwards and the succeeding turns flexed to the right. Shell bluish-white, except where the dried animal shines through its substance; there it has a granular, light brown to buff appearance. First 3 turns well rounded, separated by a well-marked suture, the remaining turns slightly rounded with scarcely defined suture. The posterior termination of the inside of the whorl shines through the shell and appears as a conspicuous false suture. Surface marked by fine lines of growth only. Periphery of the last whorl weakly angulated. Base strongly rounded on the left side. Aperture very oblique, ovate; posterior angle acute; outer lip decidedly protracted at the periphery; inner lip short, curved, slightly sinuous, reflected over and appressed to the base; parietal wall covered by a thick callus. Length, 9.5; diameter, 3 mm. (Bartsch). Departure Bay, B. C.\*—Alaska to Departure Bay, B. C.

*Melanella* (Balcis) *macra* Bartsch, 1917. (Plate 44, fig. 2). Shell of medium size, slender, with a double flexure. When viewed with the aperture to the front, it shows the early whorls bent backward and the succeeding turns flexed to the right. Shell bluish-white, except

where the dried animal shines through its substance; there it has a granular light brown to buff appearance. First 4 whorls well rounded, with well-impressed suture, the remainder almost flattened, marked by exceedingly fine lines of growth only, and separated by a scarcely visible suture. The posterior limit of the inside of the whorls shines through the substance of the shell and appears as a conspicuous false suture. Periphery of the last whorl weakly angulated. Base somewhat prolonged, well rounded. Aperture long, ovate; posterior angle acute; outer lip considerably protracted, particularly so at the periphery; inner lip stout, curved, reflected over and appressed to the base; parietal wall covered by a thick callus. Length, 7.5; diameter, 1.9 mm. (Bartsch). Off San Juan Island, Wash.; Victoria and Burrard Inlet, B. C.\*—Departure Bay, B. C., to Seattle, Wash.

*Melanella* (Balcis) *montereyensis* Bartsch, 1917. (Plate 39, fig. 6, Proc. U. S. Nat. Mus., vol. 53). Shell broadly conic, falcate, flexed to the right, bluish-white, with a series of opaque areas, marking varical streaks. Early whorls well rounded, the later ones slightly rounded, a little more so on the concave than the convex side. Sutures scarcely marked. The posterior determination on the inside of the turns, shines through the substance of the shell and appears as a conspicuous false suture. Periphery weakly angulated. Base short, very strongly curved on the left side. Aperture short, broadly oval; posterior angle acute; outer lip quite strongly protracted at the periphery, inner lip oblique, curved, reflected and appressed to the base; parietal wall covered by a thick callus. Length, 5; diameter, 2.2 mm. (Bartsch). Off Brown Island, Wash., in clumps of *Mytilus*, in 25 fathoms.\*—Puget Sound to Monterey, Calif.

*Melanella* (Balcis) *comoxensis* Bartsch, 1917. (Plate 44, fig. 3). Shell broadly conic, with a double flexure, the early portion being turned back while the latter is turned to the right; bluish-white, polished. First 2 whorls well rounded, separated by a constricted suture, the rest slightly rounded, a little more so on the convex than the concave side, marked by exceedingly fine lines of growth and microscopic spiral striations, and occasional varical streaks, which appear as an opaque spot in the shell. Suture scarcely defined. The posterior limit of the inside of the whorls shines through the substance of the shell and appears as a false suture. Periphery broadly oval; rather short; posterior angle acute; outer lip protracted at the periphery; inner lip short, slightly curved, strongly reflected and appressed to the base; parietal wall covered with a thick callus. Length, 7.1; diameter, 3 mm. (Bartsch).—Known only from Comox, B. C.\*



**Family PYRAMIDELLIDAE****TURBONILLA** Risso, 1826

Shell with a sinistral apex, cylindro-conic, many whorled, generally slender, with a single columella fold which varies in strength and frequently is not visible in the aperture. The sculpture both axial and spiral ranges from obsolete to strongly incised raised lines or raised lamellae. (Bartsch). Type *T. typica* Dall & Bartsch.

*Turbonilla* (Chemnitzia) *engbergi* Bartsch, 1920. Shell small, elongate conic, thin, semitransparent, bluish white. Nuclear whorls decollated. Postnuclear whorls moderately rounded, appressed at the summit, marked by broad, slightly protractively slanting axial ribs, of which 14 occur upon all of the remaining turns, except the last, on which there are 16. These ribs are a little broader than the spaces that separate them, and they become slightly flattened and weaker toward the summit. The intercostal spaces are deeply depressed pits, which terminate somewhat posterior to the summit of the succeeding turn, leaving a broad, smooth bend at the suture. Suture strongly constricted. Periphery of the last whorl well rounded, not crossed by the strong axial ribs. Base short, well rounded, marked by incremental lines only. Aperture subquadrate, posterior angle obtuse; outer lip thin; inner lip slightly sinuous, decidedly obliquely inserted, the inner edge having a decidedly protractive slant; parietal wall devoid of callus. Altitude, 3.7; diameter, 1.1 mm. San Juan Island, Wash.\*—Gulf of Georgia and Puget Sound.

*Turbonilla* (Strioturbonilla) *vancouverensis* Baird, 1863. (Plate 44, fig. 1, Proc. U. S. Nat. Mus., vol. 30). Shell solid, rather broad and stout, subdiaphanous, bluish to milk-white. Nuclear whorls 2, large, helicoid, partly obliquely immersed in the first of the later turns. Post-nuclear whorls well rounded, with the greatest convexity on the lower half of the exposed portion; ornamented by about 10 very broad, strong, slightly protractive axial ribs on the second, 14 on the fifth, 16 on the eighth, and 18 on the penultimate whorl. These ribs terminate before they reach the periphery of the whorl, leaving a plain band above the suture as in *T. torquata* Gould, but not as broad as in that species. Intercostal spaces deep, narrower than the ribs. Sutures well marked by the shouldering at the summit and the sudden sloping of the ribs just above the periphery of the whorls. Aperture subovate; lip thin, joining the short, somewhat revolute columella in an even curve. Entire surface marked by faint, wavy, spiral striations. Length, .6; diameter, 1.8 mm. (Bartsch). Departure Bay, B. C.\*—Port Etches, Alaska, to Puget Sound.

*Turbonilla* (*Strioturbonilla*) *kincaidi* Bartsch, 1921. Shell rather broadly elongate conic, yellowish white. Nuclear whorls decollated. The remaining turns are moderately well rounded and somewhat overhanging, appressed at the summit, decidedly constricted at the suture, marked by rather depressed, slightly retractively slanting axial ribs, of which 18 occur upon the first of the remaining turns, and 20 upon all the other turns. The spaces which separate the ribs are moderately impressed and terminate roundly about one-eighth of the distance between the summit and the suture, anterior to the suture; periphery of the last whorl well rounded. Base short, inflated, well rounded, marked by feeble continuation of the axial ribs, which become evanescent before reaching the umbilicus. In addition to the above sculpture the entire surface of the spire and base is marked by very fine closely spaced spiral striations. Aperture rather large, very broadly oval, almost subquadrate; posterior angle obtuse; outer lip thin, showing the external sculpture within; inner lip slender, somewhat sinuous, reflected over and appressed to the base for three-fourths of its length; parietal wall covered by a moderately thick callus. Length, 5.5; diameter, 1.7 mm. Liberty Bay (Dogfish Bay) near Poulsbo, Wash., by Prof. T. C. Kincaid.\*—Puget Sound.

*Turbonilla* (*Strioturbonilla*) *barkleyensis* Bartsch, 1917. (Plate 42, fig. 8; and plate 44, fig. 9; Proc. U. S. Nat. Mus., vol. 52). Shell large, slender, elongate conic, bluish white. Nuclear whorls small, a little more than  $2\frac{1}{4}$ , depressed helicoid, having their axis at right angles to that of the succeeding turn, in the first of which they are slightly immersed. Postnuclear whorls well rounded, appressed at the summit, marked by slender, curved, moderately regular, slightly protractive, axial ribs, of which 16 occur upon the first to fifth, 18 upon the sixth, 22 upon the seventh and eighth, 24 upon the ninth and tenth, and 26 upon the penultimate turn. Intercostal spaces moderately impressed, terminating a little posterior to the periphery of the whorl. The summit of the succeeding turns falls a little anterior to the termination of the intercostal pits and leaves a smooth band in the suture. Suture moderately constricted. Periphery of the last whorl obtusely angulated. Base moderately long, weakly rounded. The entire surface of the shell is marked by microscopic striations. Aperture large, broad, subquadrate, somewhat effuse at the junction of the basal and the outer lip, posterior angle obtuse; outer lip very thin, showing the external sculpture within; inner lip decidedly oblique, slightly curved and somewhat revolute; partial wall covered by a thin callus. Length, 9.2; diameter, 2 mm. (Bartsch).—Known only from Barkley Sound, Vancouver Island, B. C.

*Turbonilla* (Strioturbonilla) *stylina* Carpenter, 1865. (Plate 3, fig. 7, Bull. U. S. Nat. Mus., No. 68). Shell slender, subdiaphanous to milk-white. Nuclear whorls 2, smooth depressed, helicoid, scarcely extending beyond the outline of the spire and having their axis at right angles to the succeeding turns. Post-nuclear whorls well rounded, separated by strongly constricted sutures, rather high, ornamented by rather low, broad, rounded, sinuous, protractive axial ribs, of which there are 16 upon the first, 20 upon the fifth, and 28 upon the penultimate turn. Intercostal spaces moderately depressed, about as wide as the ribs, terminating a short distance above the sutures, thus leaving a narrow, smooth band between the termination of the ribs and in the suture as in *T. torquata* Gould, but not quite as wide as in that species. Periphery of the last whorl well rounded. Base rather short, well rounded. Entire surface marked by very fine, wavy spiral striations. Aperture subovate, outer lip thin; columella slender, moderately long, slightly twisted, almost vertical. Length, 6.5; diameter, 1.7 mm. (Bartsch). Off Nanaimo, B. C.\*—Vancouver Island to Coronado Islands, Mex.

*Turbonilla* (Pyrgolampros) *victoriana* Dall & Bartsch, 1907. (Pl. 44, fig. 6, Proc. U. S. Nat. Mus., vol. 3; also pl. 5, fig. 3, Bull. U. S. Nat. Mus., No. 68). Shell elongate-conic, wax yellow to light brown. Nuclear whorls and the early succeeding turns eroded on all the specimens examined. Post-nuclear whorls quite high between the sutures, somewhat convex in the posterior two-thirds of the exposed portion, only slightly contracted toward the periphery and faintly shouldered at the summit; ornamented by low, rounded, somewhat sinuous axial ribs, which are about as wide as the shallow intercostal spaces. Sutures well marked. Periphery and base of the last whorl somewhat inflated, marked by weak continuations of the axial ribs which extend feebly to the umbilical region. Entire surface crossed by numerous, wavy spiral striations. Aperture rather elongate, oval, outer lip thin; columella moderately long, decidedly twisted and somewhat revolute in its free anterior portion; the twist at its insertion appearing as a fold. Length, 7; diameter, 2.1 mm. (Bartsch).—Known only from Victoria, B. C.\*

*Turbonilla* (Pyrgolampros) *newcombei* Dall & Bartsch, 1907. (Pl. 45, fig. 6, Proc. U. S. Nat. Mus., vol. 33). Shell regular, broadly conic, white on the posterior half and light brown on the anterior half of the exposed portion of the whorl; base white. Nuclear whorls decollated on all the specimens seen. Post-nuclear whorls somewhat overhanging, decidedly contracted toward the periphery from the an-

terior fifth of the exposed part; almost flattened posterior to this, and closely appressed at the summit, separated by strongly marked sutures. Ribs about 18 upon all the turns, almost vertical, moderately elevated, rounded in the middle, decidedly flattened and widened at the summit, disappearing at the periphery. Intercoastal spaces not depressed below the general surface, a little wider than the ribs. Periphery and the moderately long base well rounded, smooth, excepting the fine spiral striation which covers the entire surface of the shell. Aperture subquadrate, posterior angle acute; outer lip thin, showing the color bands within; columella slender, oblique and slightly revolute. Length, 5.4; diameter, 2.1 mm. (Dall & Bartsch). Victoria, B. C. Dr. C. F. Newcombe.—Port Simpson, B. C., to Victoria, B. C.

*Turbonilla* (Pyrgolampros) *taylori* Dall & Bartsch, 1907. (Pl. 44, fig. 9, Proc. U. S. Nat. Mus., vol. 33). Shell very regularly elongate-conic, purplish-brown. Entire surface marked by numerous closely placed minute spiral striations. Nuclear whorls small, depressed helicoid, smooth, scarcely at all immersed, having their axis at a right angle to that of the later turns, the sides not projecting beyond the spire. Post-nuclear whorls quite high between the sutures, only slightly contracted toward the periphery and very weakly beveled at the appressed summits, marked by low, broad, retractive axial ribs, which are much more numerous and less strongly defined on the early whorls than on those succeeding. There are about 36 on the second, 30 upon the third, 24 upon the fourth, and 26 upon the antepenultimate post-nuclear turn. On the last whorl they become irregular and irregularly spaced, showing senility. The ribs become flattened and less strongly defined toward the summit and the periphery disappearing at the well-rounded periphery. Sutures well marked. Base short, inflated, rounded. Aperture suboval, somewhat effuse anteriorly; posterior angle acute; outer lip thin, white edged, chestnut brown within except at the very base, which is white; columella slender, twisted, and slightly revolute anteriorly. Length, 6.5; diameter, 1.9 mm. (Dall & Bartsch). Departure Bay, B. C., by Rev. G. W. Taylor.—Port Simpson, B. C., to Strait of Fuca.

*Turbonilla* (Pyrgolampros) *aurantia* Carpenter, 1865. (Pl. 6, fig. 4, Bull. U. S. Nat. Mus., No. 68). Shell similar to *T. chocolata* Carpenter, but much broader, with the close spiral striation a little more pronounced than in that species, covered by a golden-yellow epidermis. Nuclear whorls decollated in all our specimens. Post-nuclear whorls moderately rounded, but little contracted at the base

and very slightly shouldered at the summit, ornamented by about 22 moderately developed, slightly retractive axial ribs on each of the whorls. These ribs become quite obsolete as they pass over the well-rounded periphery and base of the last whorl. Intercoastal spaces weak, much narrower than the ribs. Sutures quite prominent, simple. Aperture large, broadly ovate, posterior angle obtuse, somewhat effuse at base; outer lip thin, columella slender, quite oblique, twisted, and revolute. Length, 5.8; diameter, 2.4. (Bartsch). Turn Island, Wash., at roots of the eelgrass.\*—Departure Bay, B. C., to Puget Sound.

*Turbonilla* (Pyrgolampros) *pugetensis* Bartsch, 1917. (Pl. 44, fig. 4, Proc. U. S. Nat. Mus., vol. 52). Shell small, elongate conic, wax yellow with a broad band of pale brown which extends posterior from the periphery, gradually fading into the general color. Nuclear whorls and early postnuclear turns decollated in all our specimens; those remaining feebly shouldered at the summit, flattened in the middle, becoming considerably contracted and rounded toward the suture, marked by broad, well rounded slightly protractive axial ribs which become somewhat enfeebled and expanded toward the summit. Of these ribs 16 occur upon all of the turns remaining excepting the last which has 18. Intercoastal spaces shallow, about as wide as the ribs. Suture moderately contracted. Periphery of the last whorl well rounded. Base somewhat inflated, well rounded, marked by the feeble continuations of the axial ribs which become evanescent before reaching the middle of the base and numerous very fine spiral striations which are present on the spire. Aperture broadly oval; posterior angle acute; outer lip thin showing the external sculpture within; inner lip decidedly oblique, slender and somewhat revolute; parietal wall glazed with a very thin callus. Length, 4; diameter, 1.5 mm. (Bartsch). Burrard Inlet, B. C., by Dr. C. M. Fraser.\*—Vancouver, B. C., to Puget Sound.

*Turbonilla* (Pyrgolampros) *talma* Dall & Bartsch, 1910. (Plate 13, fig. 3). Shell broadly elongate-conic, dark chestnut brown, wax-yellow at the apex and the columella area. Nuclear whorls decollated. Post-nuclear whorls moderately rounded, feebly shouldered at the summit, marked by strong, well-rounded, axial ribs, of which 18 occur upon each of the turns. Intercoastal spaces about two-thirds as wide as the ribs, well impressed. Sutures strongly impressed. Periphery of the last whorl well rounded. Base moderately long and well rounded, showing scarcely any traces of the axial ribs. Entire surface of spire and base crossed by numerous fine, closely spaced, spiral striations. Aperture oval; posterior angle acute; outer lip thin,

showing a lighter band half way between the periphery and the summit, in the general chestnut coloration; inner lip slender, twisted and slightly revolute, white. Length, 9; diameter, 2.8 mm. (Dall & Bartsch). Barkley Sound, Vancouver Island.—Vancouver Island.

*Turbonilla* (Pyrgolampros) *valdezi* Dall & Bartsch, 1907. (Pl. 44, fig. 3, Proc. U. S. Nat. Mus., vol. 33; also pl. 6, fig. 8, Bull. U. S. Nat. Mus., No. 68). Shell inflated, robust, broad and stumpy, of light fulvous coloration. Nuclear whorls decollated in the type. Post-nuclear whorls flattened, somewhat contracted at the periphery and rounded at the summit, traversed by broad, coarse, irregularly slanting axial ribs, which extend over the inflated periphery of the last whorl to the umbilical region, appearing less prominent on the base. About 16 of these ribs occur upon the second, 18 upon the fifth, and 24 upon the penultimate post-nuclear whorl. Entire surface of the shell crossed by very minute, close spiral striation. Surface subchanneled and wavy. Aperture ovate, outer lip thin, joining the twisted and revolute columella in a broad curve. Length, 5.6; diameter, 2.1 mm. (Dall & Bartsch). Barkley Sound, Vancouver Island.—Barkley Sound, B. C., to Monterey, Calif.

*Turbonilla* (Pyrgolampros) *pedroana* Dall & Bartsch, 1903. (Pl. 2, fig. 3, Mem. Calif. Acad. Sci., vol. 3). Shell elongate-conic, posterior two-thirds between the sutures light brown, anterior third and base darker, the 2 areas being separated by a still darker narrow band, (nuclear whorls decollated). Post-nuclear whorls flattened in the middle, rounded toward the summit and the suture, ornamented by broad, low, well rounded, slightly protractive axial ribs, which become slightly flattened toward the summit; of which 16 appear upon the first and second, 18 upon the third to fifth, 20 upon the sixth, 22 upon the seventh and the penultimate turn. Intercostal spaces almost as wide as the ribs, shallow. Sutures well impressed. Periphery and the rather short base of the last whorl somewhat inflated and well rounded. Entire surface of spire and base marked by well incised, closely spaced, fine spiral striations; aperture rather small, oval; posterior angle acute; outer lip thin, showing the external sculpture and coloration within; columella sigmoid, slender and slightly revolute. Length, 7; diameter, 2.3 mm. (Dall & Bartsch). Victoria, B. C.—Victoria, B. C., to San Diego, Calif.

*Turbonilla* (Pyrgolampros) *lyalli* Dall & Bartsch, 1907. (Pl. 44, fig. 4, Proc. U. S. Nat. Mus., vol. 33). Shell small and slender, with strong sculpture, whitish with a broad chestnut band which extends almost halfway over the exposed portion of the whorls above the

periphery and an equal distance anteriorly over the base below the periphery. Nuclear whorls 2, closely appressed to each other, forming a polished depressed helicoid spire, which does not extend beyond the outline of the post-nuclear spire, is not at all immersed and has its axis at right angles to the axis of the succeeding turns. Post-nuclear whorls decidedly flattened, moderately contracted at the periphery, and slightly shouldered at the summit, ornamented by strongly elevated, moderately broad, rounded retractive axial ribs, which become somewhat flattened toward the summit and periphery of the turns. There are about 22 ribs upon the second, 20 upon the fifth and the penultimate turn. Upon the first they are weakly expressed. Intercoastal spaces broad, almost double the width of the ribs. Sutures strongly impressed. Periphery and the base of the last whorl well rounded, marked by the continuations of the axial ribs which extend feebly to the umbilical region. Entire surface marked by numerous closely placed spiral striations. Aperture pyriform, posterior angle acute, columella almost straight, obliquely inserted, slightly revolute. Length, 5.7; diameter, 1.4 mm. (Dall & Bartsch). Banks Island, B. C., in Rev. G. W. Taylor's collection.—Banks Island, B. C.

*Turbonilla* (*Pyrgolampros*) *macouni* Dall & Bartsch, 1910. (Plate 12, fig. 9). Shell large, very broadly elongate-conic, pale wax-yellow, with 3 chestnut bands. The first of these bands extends over the posterior fourth of the whorls between the sutures, and is less strongly colored than the other 2 which are very pronounced, about half as wide as the first, and occupy the space immediately anterior and posterior to the periphery, the space which separates them being a little narrower than the band. Nuclear whorls small, almost 2; depressed helicoid, having their axes almost at right angles to that of the succeeding turns; scarcely at all immersed. Post-nuclear whorls flattened on the posterior two-thirds between the sutures, slightly rounded anteriorly; moderately shouldered at the summit; marked by strong, well-rounded, somewhat sinuous, almost vertical, axial ribs which are about as wide as the spaces which separate them. Of these ribs 18 occur upon the second, 20 upon the third and fourth, 18 upon the fifth to seventh, 20 upon the eighth and ninth, 22 upon the tenth and penultimate turn. Periphery of the last whorl well rounded. Base of the last whorl moderately long, well rounded, marked by feeble continuations of the axial ribs. Entire surface of spire and base marked by numerous, closely spaced, very fine, spiral striations. Aperture moderately large, broadly oval; posterior angle obtuse; outer lip thin, showing the external markings within; inner lip slender, moderately curved and slightly revolute; parietal wall glazed with a

thin callus. Length, 9; diameter, 3 mm. (Dall & Bartsch).—Known only from Barkley Sound, Vancouver Island.

*Turbonilla* (Pyrgolampros) *pesa* Dall & Bartsch, 1910. (Plate 13, fig. 5). Shell elongate-conic, small, chestnut brown, with a slightly paler, broad, obscure band half way between the sutures. Nuclear whorls decollated. Postnuclear whorls flattened, slightly shouldered at the summit, marked by feeble, almost vertical, axial ribs, of which 22 occur upon the second, 24 upon the third, 20 upon the fourth and fifth, and 26 upon the sixth of the remaining turns. Upon the penultimate turn the ribs are subobsolete. Intercostal spaces feebly impressed, of irregular width. Sutures well impressed. Periphery of the last turn somewhat inflated, well rounded. Base short, well rounded. Entire surface of spire and base crossed by numerous very fine, closely spaced, spiral striations. Aperture broadly oval; posterior angle acute; outer lip thin, showing the external markings within by transmitted light; inner lip moderately strong, slightly curved and revolute. Length, 6; diameter, 1.6 mm. (Dall & Bartsch).—Known only from Barkley Sound, Vancouver Island, B. C.

*Turbonilla* (Pyrgolampros) *rinella* Dall & Bartsch, 1910. (Plate 12, fig. 2). Shell elongate-conic, reddish wax-yellow, a little lighter on the posterior half between the sutures; anterior half of base almost white. Nuclear whorls decollated. Posterior two-thirds of the post-nuclear whorls between the sutures flattened; anterior third rounding moderately toward the periphery; whorls marked by feebly developed, low, broad, retractive, axial ribs, which are separated by narrow, shallow, intercostal spaces. Of these ribs, 22 occur upon the fourth, 24 upon the fifth and sixth, 26 upon the seventh, and about 42 upon the last of the remaining turns. Upon the last they are very irregular and even less strongly developed than on the preceding. Suture well impressed. Periphery of the last whorl somewhat inflated, well rounded, with scarcely any traces of axial sculpture. Entire surface of spire and base marked with numerous wavy, closely spaced, spiral striations. Aperture broadly oval; posterior angle acute; outer lip thin, inner lip oblique, slender, and revolute; parietal wall covered with a fairly thick callus. Length, 8.5; diameter, 2.3 mm. (Dall & Bartsch).—Known only from Barkley Sound, Vancouver Island, B. C.

*Turbonilla* (Mormula) *lordi* E. A. Smith, 1880. (Pl. 11, fig. 4, Bull. U. S. Nat. Mus., No. 68). Shell very heavy, light brown to pale yellowish-white, variously banded. Nuclear whorls two, smooth, helicoid, moderately elevated, having their axis at right angles to the axis of the succeeding turns and about immersed in the first of them.



Post-nuclear whorls well rounded, ornamented by heavy, broad, low axial ribs, of which about 14 occur upon the second, 16 upon the eighth, 22 upon the eleventh, and 30 upon the penultimate whorl. Intercostal spaces not deeply depressed, about as wide as the ribs, ornamented by about 12-15 irregularly spaced spiral striations between the sutures; those near the summit of the whorls are closer and more feeble than those near the periphery of the whorls. Sutures strongly impressed, somewhat wavy. Periphery of the last whorl somewhat angulated in young specimens, moderately well rounded in adults. Base rather short, marked by faint continuations of the axial ribs and faint wavy spiral striation. Aperture subrhombic, posterior angle obtuse, outer lip thin, showing the external sculpture and banding within; columella stout, slightly twisted and revolute, provided with an oblique internal fold. The color markings in the specimen here described and figured consist of a pale yellowish-brown band, about  $\frac{1}{4}$  the width of the whorl between the sutures, covering the posterior part, followed by a narrow band of the yellowish-white ground color, which is followed by a band of brown a little darker than the first and about as wide as the last-named white band; then a broad pale white band, lastly a narrow yellow one above the periphery finishes the markings between the sutures. The periphery is marked by a narrow band of white followed by a deep brown one which shades gradually to the white about the umbilical region. Length, 20.8; diameter, 5.1 mm. (Bartsch). This is the largest species of this group known from the west coast of America. Banks Island, B. C., by Rev. G. W. Taylor.—Sitka, Alaska, to Puget Sound.

*Turbonilla eschscholtzi* Dall & Bartsch, 1907. (Plate 46, fig. 8). Shell large, elongate-conic, brown, having 3 obscure bands of dark brown, one of which is at the summit, another at the periphery, while the third is halfway between these on the exposed portion of the whorl of the spire. Nuclear whorls decollated. Post-nuclear turns moderately rounded, ornamented by low, rounded, rather distantly spaced, slightly protractive axial ribs which become weakened and somewhat flattened as they approach the appressed summit, and many fine lines of growth both on the ribs and in the intercostal spaces. In addition to the axial sculpture the whorls are crossed by 12 deeply incised, somewhat irregularly spaced spiral lines, the raised spaces between which are again divided by many fine striae. All the spiral markings pass over the intercostal spaces and the ribs. Periphery of the last whorl obscurely angular, marked by the feeble continuations of the ribs which vanish immediately below the periphery and the usual fine lines of growth and spiral striation. Base rather short,

well rounded, brown with a narrow whitish band about the umbilicus, marked by closely spaced continuous wavy spiral striation, which varies in strength, several finer striae alternating with the stronger. Aperture subquadrate, outer lip thin, showing 4 narrow dark-brown bands within, upon a lighter background—these are the 3 already referred to—and a fourth one on the base adjoining the periphery; columella almost vertical, slightly twisted and revolute. Length, 13.3; diameter, 4 mm. (Bartsch). Brandon Island, Departure Bay, B. C., in 1920.\*—Port Simpson, B. C., to Departure Bay, B. C.

#### ODOSTOMIA Fleming, 1817

Shell with sinistral apex, usually short, few whorled, subconic or ovate, with a single columella fold which varies in strength and sometimes is not apparent at the aperture. The sculpture varies from smooth to lamellar axial ribs and spiral keel. (Bartsch). Type *Turbo plicatus* Montagu. Of the 40 subgenera now recognized under *Odosstomia* 19 have been found represented on the west coast of America.

*Odostomia* (Chrysallida) *oregonensis* Dall & Bartsch, 1907. (Pl. 45, fig. 8). Shell elongate-conic, slender, subdiaphanous to milk-white. Nuclear whorls immersed, the last one only being visible. This is somewhat tilted and marked by 3 strong narrow spiral keels and many slender raised threads which cross the grooves between the keels. Postnuclear whorls well rounded, slopingly shouldered at the summit and separated by constricted sutures, ornamented by almost equal and equally spaced spiral keels and axial ribs between the sutures on the spire. There are 4 spiral keels on the first, second, and third whorls, 6 on the fourth, and 7 upon the penultimate whorl. The first of these keels is on the shoulder of the whorl near the summit and is somewhat less developed than the rest. The axial ribs are best developed on the early whorls, where they extend equally strong from the summit to the periphery; on the antepenultimate and penultimate turns they become somewhat enfeebled from the middle of the whorl between the suture to the periphery. There are about 16 of these ribs on the first, 18 on the third, 20 upon the fourth, and 22 upon the penultimate turn. The intersections of the ribs and spiral keels form low elongated tubercles, the long axis of which coincides with the spiral sculpture. The meshes enclosed by the keels and ribs are deeply impressed squarish pits. Periphery and base of the last whorl well rounded, the latter somewhat inflated and marked by 6 spiral cords which are successively closer spaced and a little less strongly developed from the periphery to the umbilical area. The channels between the cords are crossed by many very slender raised vertical

threads. Aperture oval, slightly effuse anteriorly; outer lip thin; columella reenforced on its posterior two-thirds by the attenuated base, free and somewhat revolute anteriorly; partial wall glazed by a thin callus. Length, 3.3; diameter, 1.2 mm. (Dall & Bartsch). Cumshewa Inlet, Queen Charlotte Islands, in 10 fathoms.—Queen Charlotte Islands to Monterey, Calif.

*Odostomia* (Chrysallida) *cumshewaensis* Bartsch, 1921. Shell broadly elongate conic, milk white, nuclear whorls at least 2, obliquely immersed in the first of the postnuclear whorls, above which about two-thirds of the nuclear spire projects. Postnuclear whorls strongly rounded, constricted at the periphery, marked by strong, retractively slanting axial ribs, of which 16 occur upon the first, 18 upon the second, 22 upon the third and the penultimate turn. These ribs are crossed by 4 strong spiral cords which are a little wider than the ribs, and render the axial ribs tuberculated, the first row of tubercles at the summit being decidedly smaller than the 2 that succeed it. All 3 of these have the tubercles strongly, evenly rounded. The fourth immediately above the periphery, however, has the spiral cord stronger than the axial ribs, and appears as an almost uninterrupted cord with feebler tubercles. The pits enclosed between the ribs and spiral cords are strongly impressed and rounded. Suture strongly constricted, a part of the first basal cord showing at the suture of the last 2 turns. Periphery well rounded, marked by a strong spiral cord. Base moderately long, marked by 5 spiral cords on the anterior three-fourths, which become succeedingly narrower and feebler, the last 2 being indicated merely by the incised lines that separate them. The anterior fourth of the base is smooth, excepting incremental lines. The spaces between the spiral cords on the base are crossed by fine axial threads. Aperture very broadly oval; posterior angle obtuse; outer lip thin, showing the external sculpture within; inner lip strongly curved, reflected over and appressed to the base, a very narrow chink remaining behind the lip, indicating a very slight umbilicus; parietal wall covered by a thick callus. Length, 2.7; diameter, 1.2 mm. (Bartsch).—Known only from Cumshewa Inlet, Queen Charlotte Islands.

*Odostomia* (Menestho) *pharcida* Dall & Bartsch, 1907. (*O. tenuis* Dall). (Plate 45, fig. 10). Shell small, subcylindric, yellowish-white. Nuclear whorls deeply immersed, a portion of the last and the penultimate only appear when viewed from the side; this gives the shell a truncated appearance. Postnuclear whorls moderately well-rounded, rather wide between the sutures, and somewhat shouldered

at the summits; ornamented by strong, low, rounded spiral cords, which are separated by moderately deep, narrow, depressed channels. Six of these cords occur upon the first, 7 upon the second to penultimate whorl between the sutures; the posterior cord is a little broader and less elevated than the rest, while some of those on the penultimate turn show a tendency to divide, that is a faint spiral line is apparent on the middle of some of those cords. Sutures well impressed. Periphery and base of the last whorl well rounded, the latter ornamented by 8 rounded spiral cords similar to those between the sutures. The spaces between the spiral ridges on the base and between the sutures are marked by closely placed, exceedingly slender, raised axial threads. Aperture pyriform, somewhat effuse anteriorly, posterior angle acute; columella short, curved, reenforced by the attenuated base, free only at its extreme anterior end, with an oblique fold near its insertion; parietal wall covered by a thin callus. Length, 2.2; diameter, 0.9 mm. (Dall & Bartsch). Cumshewa Inlet, B. C., in 10-15 fathoms, by Dr. C. F. Newcombe.—Cumshewa Inlet, Queen Charlotte Islands.

*Odostomia* (Evalea) *youngi* Dall & Bartsch, 1910. (Plate 13, fig. 1). Shell, elongate-conic, umbilicated, milk-white. Nuclear whorls small, obliquely immersed in the first of the post-nuclear turns, above which only the tilted edge of the last volution projects. Post-nuclear whorls moderately rounded, with a narrow tabulatedly shouldered summit, marked by equally spaced, rather strong, spiral striations, of which about 32 occur between the summit and the periphery on the penultimate turn. Periphery and base of the last whorl inflated, well rounded, marked with spiral sculpture equal in strength and disposition to that on the spire. Sutures strongly impressed. In addition to the spiral sculpture, the whorls are marked with curved retractive lines of growth. Aperture pear-shaped; posterior angle acute; outer lip thin; inner lip slender, curved, and somewhat revolute, provided with a strong oblique fold a little anterior to its insertion; parietal wall glazed with a thick callus. Length, 6.5; diameter, 2.4 mm. (Dall & Bartsch). Olga, Orcas Island, Wash., by C. C. Engberg.—Barkley Sound, Vancouver Island, to Puget Sound.

*Odostomia* (Evalea) *quadrae* Dall and Bartsch, 1910. (Plate 13, fig. 6). Shell elongate-ovate, milk-white, umbilicated. Nuclear whorls deeply, obliquely immersed in the first of the post-nuclear turns, above which only the tilted edge of the last volution projects. Post-nuclear whorls moderately rounded, moderately shouldered at the summit, marked by faint, slightly retractive lines of growth, and numerous,

exceedingly fine, microscopic, spiral striations. In addition to this sculpture, the last whorl shows many weak malleations. Periphery of the last whorl and the moderately long base somewhat inflated, well rounded, marked like the spire. Aperture large, oval; posterior angle acute; outer lip thin; columella very oblique, slightly curved and strongly revolute, extending partly over the umbilicus, provided with a moderately strong fold a little anterior to its insertion; parietal wall glazed with a thin callus. Length, 6.2; diameter, 3.2 mm. (Dall & Bartsch). Inside Dodds Narrows, Vancouver Island; Liberty (Dogfish) Bay, near Poulsbo, Wash.\*—Vancouver Island to Poulsbo, Wash.

*Odostomia* (Evalea) *spreadboroughi* Dall & Bartsch, 1910. (Plate 13, fig. 2). Shell elongate-ovate, somewhat translucent, bluish-white. Nuclear whorls small, deeply very obliquely immersed within the first of the succeeding turns. Post-nuclear whorls inflated, flattened in the middle, rounded strongly at the summit and the suture, marked by decidedly sinuous, exceedingly fine lines of growth and fine spiral striations; the latter are less strongly developed on the posterior two-thirds between the sutures than on the anterior third and on the base. Sutures strongly constricted. Periphery of the last whorl and base inflated, well rounded, the latter deeply and strongly umbilicated. Aperture oval; posterior angle acute; outer lip thin, showing the external sculpture within; columella very slender, strongly curved and slightly revolute, provided with a very faint, oblique fold a little anterior to its insertion; parietal wall glazed with a thin callus. Length, 3.8; diameter, 1.9 mm. (Dall & Bartsch).—Known only from Ship Channel, Blakely Sound, Vancouver Island.

*Odostomia* (Evalea) *vancouverensis* Dall & Bartsch, 1910. (Pl. 13, fig. 7). Shell elongate-ovate, very narrowly umbilicated, turreted, yellowish-white. Nuclear whorls small, obliquely immersed in the first of the succeeding turns, above which only half of the last volution projects and extends beyond the outline of the spire. Post-nuclear whorls broadly, tabulatedly shouldered at the summit, moderately rounded, marked by almost vertical lines of growth and numerous exceedingly fine spiral striations. Sutures rendered very conspicuous by the tabulated shoulder. Periphery of the last whorl well rounded, base moderately long, well rounded, marked like the spire. Aperture large, elongate-ovate, somewhat effuse anteriorly; posterior angle decidedly obtuse; outer lip thin; inner lip slender, oblique, and somewhat revolute, provided with an oblique fold a little anterior to its insertion; parietal wall glazed with a thin callus. Length, 4.7; di-

ameter, 2.2 mm. (Dall & Bartsch). Olga, Orcas Island, Wash., by C. C. Engberg.—Barkley Sound, Vancouver Island, to Puget Sound.

*Odostomia* (Evalea) *cypria* Dall & Bartsch, 1910. (Pl. 37, fig. 9, Proc. U. S. Nat. Mus., vol. 42). Shell of medium size, narrowly elongate-ovate, umbilicated, yellowish-white. (Nuclear whorls decolated). Post-nuclear whorls rather high between the sutures, moderately rounded, very feebly shouldered at the summit, marked by very fine lines of growth and numerous exceedingly fine, closely-spaced, spiral striations. Sutures very slightly constricted. Periphery of the last whorl very rounded. Base moderately long, well rounded, narrowly umbilicated. Aperture broadly oval, effuse anteriorly; posterior angle obtuse; outer lip thin; inner lip very oblique, slightly curved and revolute, not appressed to base, provided with a very deep-seated feeble fold at its insertion; parietal wall covered with a thick callus, which renders the peritreme complete. Length, 4; diameter, 2 mm. (Dall & Bartsch).—Known only from Skidegate, Queen Charlotte Islands.

*Odostomia* (Evalea) *hypatia* Dall & Bartsch, 1912. (Pl. 37, fig. 5, Proc. U. S. Nat. Mus., vol. 42). Shell large, elongate-ovate, strongly umbilicated, yellowish-white. Nuclear whorls deeply immersed in the first of the succeeding turns, above which the tilted edge of the last volution only projects. Post-nuclear whorls well rounded, feebly shouldered at the summit, marked by fine incremental lines, and numerous exceedingly fine closely spaced, spiral striations. Sutures moderately constricted. Periphery of the last whorl inflated, well rounded. Base moderately long, well rounded, openly umbilicated. Aperture oval, effuse anteriorly; posterior angle obtuse; outer lip thin; inner lip very oblique, slender, curved, and decidedly reflected, but not appressed to the base, provided with a moderately strong fold a little anterior to its insertion; parietal wall glazed with a thin callus. Length, 5.2; diameter, 2.8 mm. (Dall & Bartsch).—Known only from Skidegate, Queen Charlotte Islands.

*Odostomia* (Evalea) *barkleyensis* Dall & Bartsch, 1910. (Plate 13, fig. 8). Shell small, regularly conic, bluish-white. Nuclear whorls deep, obliquely immersed in the first of the succeeding turns, above which only the tilted edge of the last volution projects. Post-nuclear whorls slightly rounded, marked by fine retractive lines of growth and numerous fine spiral striations. Sutures strongly impressed. Periphery of the last whorl subangulated. Base rather short, sloping from the subangulated periphery to its margin, with a tumid area bounding the narrow umbilicus, marked like the spire. Aperture

oval; posterior angle acute; outer lip thin; inner lip decidedly curved and reflected, provided with a strong oblique fold at its insertion; parietal wall glazed with a moderately thick callus. Length, 3.1; diameter, 1.4 mm. (Dall & Bartsch).—Known only from Barkley Sound, Vancouver Island.

*Odostomia* (Evalea) *cassandra* Bartsch, 1912. (Pl. 38, fig. 5, Proc. U. S. Nat. Mus., vol. 42). Shell small, ovate, very thin, semi-transparent, light yellow. Nuclear whorls deeply immersed in the first of the succeeding turns. Post-nuclear whorls very strongly, tabulately shouldered at the summit, moderately rounded, marked by fine incremental lines, and numerous exceedingly closely spaced, very fine, spiral striations. Sutures strongly constricted. Periphery of the last whorl well-rounded. Base rather long, well-rounded. Aperture very large, broadly oval; posterior angle decidedly obtuse; outer lip very thin; inner lip very slender, very oblique, somewhat sinuous, strongly curved, and slightly reflected over the base, but not appressed to it, provided with a weak fold some little distance anterior to its insertion. Length, 2.5; diameter, 1.3 mm. (Dall & Bartsch).—Known only from Skidegate, Queen Charlotte Islands.

*Odostomia* (Evalea) *angularis* Dall and Bartsch, 1907. (Pl. 47, fig. 2, Proc. U. S. Nat. Mus., vol. 33). Shell very regularly elongate-conic, subdiaphanous to milk-white. Nuclear whorls small, deeply obliquely immersed in the first of the succeeding turns, above which the tilted edge of the last turn only is visible. Post-nuclear whorls slightly rounded, separated by constricted sutures, marked by numerous slender, wavy, subequal and subequally closely spaced spiral striations, of which about 33 occur upon the last turn between the summit and the periphery. Periphery of the last whorl marked by a slender raised keel, decidedly angulated. Base short, moderately rounded, narrowly attenuated anteriorly to reenforce the columella, sculptured like the posterior portion of the whorls. Aperture ovate, very broad, slightly effuse anteriorly; posterior angle acute; columella very slender, evenly curved, closely appressed to the attenuated base, with a strong fold at its insertion, which is barely visible when the aperture is viewed squarely. Length, 5.6; diameter, 2.8 mm. (Dall and Bartsch). Off Shaw, Olga, Orcas and San Juan Islands, Wash., in 25-30 fathoms.\*—Sitka Harbor, Alaska, to Port Harford, Calif.

*Odostomia* (Evalea) *columbiana* Dall & Bartsch, 1907. (Plate 45, fig. 5). Shell large, elongate-conic, white. Nuclear whorls small, vitreous, planorbid, deeply obliquely immersed in the first of the succeeding turns, above which only the tilted edge of the last volution

is visible. Post-nuclear whorls increasing regularly in size, well rounded, very narrowly roundly shouldered at the summits, which renders the sutures well marked. Periphery of the last whorl somewhat inflated. Base well rounded, attenuated anteriorly to reenforce the columella. Entire surface covered by numerous somewhat wavy, subequal and subequally closely placed spiral lirations, of which about 40 occur between the summit and the periphery and about an equal number on the base of the last whorl. Aperture large, decidedly patulous anteriorly; posterior angle acute; outer lip thin at the edge, very thick within; columella curved and strongly reflected, free only at its anterior extremity, provided with a strong oblique fold at its insertion. Length, 8.3; diameter, 4.2 mm. (Dall and Bartsch). Off Shaw and Orcas Islands, and in Griffin Bay, Wash., in 25-30 fathoms.\*—Port Rupert, B. C., to Puget Sound.

*Odostomia* (Evalea) *tenuisculpta* Carpenter, 1864. (Pl. 23, fig. 2, Bull. U. S. Nat. Mus., No. 68). Shell elongate-ovate, yellowish, with the early whorls spirally lirate and the later ones only obsoletely so. Nuclear whorls small, smooth, obliquely almost completely immersed in the first of the succeeding turns. Post-nuclear whorls evenly well-rounded with appressed summits. The first 3 marked between the sutures by many subequal lirae of which there are about 15 on the second turn. On the last two turns these lirations become quite obsolete. Periphery and base of the last whorl inflated and well-rounded, marked by very feeble spiral striation and lines of growth. Aperture moderately large, oval; somewhat effuse anteriorly; posterior angle acute; outer lip thin; columella strongly curved, reinforced partly by the attenuated base, moderately reflected anteriorly bearing a strong fold at its insertion which appears as if it were the inflected termination of the columella. Length, 2.3; diameter, 1.7 mm. (Bartsch). Olga, Orcas Island, Wash., shore; Griffin Bay, San Juan Island, Wash., in 25-30 fathoms.\*—Vancouver Island to Lower California.

*Odostomia* (Evalea) *skidegatensis* Bartsch. (Pl. 38, fig. 7, Proc. U. S. Nat. Mus., vol. 42). Shell elongate-conic, yellowish white. Nuclear whorls completely immersed in the first of the succeeding turns, above which only half of the last turn projects. Post-nuclear whorls very slightly rounded, feebly shouldered at the summit, marked by incised spiral lines, which are much stronger on the first 2 volutions than on the remaining. Of these lines, 10 appear upon the second turn. On the last they are reduced to exceedingly fine striations. Sutures moderately constricted. Periphery of the last whorl decidedly



inflated and feebly angulated. Base somewhat prolonged, moderately rounded, marked by fine, closely spaced, spiral striations. Aperture large, oval; posterior angle acute; outer lip thin; inner lip strong, moderately curved, and partly reflected over and appressed to the base, provided with a strong fold at its insertion. Length, 3.4; diameter, 1.6 mm. (Bartsch). Olga, Orcas Island, Wash., shore.\*—Skidegate, Queen Charlotte Islands, to Trinidad, Calif.

*Odostomia* (Evalea) *inflata* Dall & Bartsch, 1907. (Plate 45, fig. 2). Shell ovate, white. Nuclear whorls decollated. Post-nuclear whorls inflated, gently curved over the anterior two-thirds of the whorl between the sutures and more strongly so on the posterior third, this portion forming an evenly curved shoulder. Extreme summit of the whorls slightly flattened and narrow, rendering the sutures well marked. Periphery of the last whorl subangulated. Base attenuated, rather suddenly contracted below the periphery, which gives the space between the periphery and the umbilical area a concave aspect. Entire surface marked by fine lines of growth and many fine, closely placed spiral lirations, 5 of which are a little stronger than the rest and divide the space between the sutures into subequal areas. There are about 30 of these threads upon the last turn between the summit and the periphery and about 60 on the base. Aperture very large, patulous anteriorly; outer lip thin at the edge but very thick within; columella decidedly curved and revolute, reenforced to the very edge by the attenuated base, provided with a strong oblique fold at its insertion. Length, 6.2; diameter, 3.8 mm. (Dall & Bartsch).—Known only from Neah Bay, Wash.

*Odostomia* (Evalea) *willetti* Bartsch, 1917. (Pl. 43, fig. 6, Proc. U. S. Nat. Mus., vol. 52). Shell large, elongate conic, bluish white. Nuclear whorls obliquely immersed in the first of the succeeding turns, above which the tiled edge of the last volution only projects. Post-nuclear whorls moderately rounded, appressed at the summit, the early ones marked by a moderate number of strongly incised lines, while on the later whorls the incised spiral lines are finer and much more numerous, in addition to the spiral sculpture the whorls are marked by decidedly retractorily slanting, incremental lines. Suture moderately constricted. Periphery of the last whorl inflated, feebly angulated. Base attenuated, moderately rounded. Aperture oval, somewhat effuse anteriorly; posterior angle acute; outer lip thin; inner lip very oblique, stout, slightly curved, reflected over and appressed to the base, provided with a strong oblique fold at its insertion; parietal wall covered with a thick callus. Length, 5.8; diameter, 2.4 mm. (Bartsch).

Vancouver Island.\*—Prince of Wales Island, Alaska, to Vancouver Island.

*Odostomia* (Evalea) *tacomaensis* Dall & Bartsch, 1907. (Plate 45, fig. 1). Shell ovate, yellowish. Nuclear whorls small, deeply immersed in the first of the succeeding turns. Post-nuclear whorls well rounded, faintly roundly shouldered at the extreme summits. Periphery of the last whorl rounded. Base inflated, well rounded, somewhat attenuated anteriorly. Surface covered by numerous equal and equally closely spaced slender wavy striations, of which there are about 40 between the summit and the periphery of the last whorl. Base marked like the space posterior to it. In addition to the spiral sculpture the entire surface of the shell is crossed by numerous fine lines of growth. Aperture moderately large, oval, well rounded anteriorly; posterior angle acute; outer lip thin; columella curved, slightly reflected, reenforced, except at its extreme anterior end, by the attenuated base and provided with a strongly oblique fold at its insertion. Length, 4.3; diameter, 2.5 mm. Dall & Bartsch.—Known only from Tacoma, Wash.

*Odostomia* (Evalea) *stephensae* Dall & Bartsch, 1909,. (Pl. 24, fig. 5, Bull. U. S. Nat. Mus., No. 68). Shell elongate-conic, bluish-white. Nuclear whorls almost completely obliquely immersed in the first of the succeeding turns, above which only the outer edge of the last volution projects. Post-nuclear whorls rather high between the sutures, moderately rounded, ornamented by numerous fine but well incised subequal and subequally spaced spiral lines; about 33 of which appear between the summit and the periphery of the last whorl. Suture well marked. Periphery of the last whorl well rounded. Base rather prolonged, well rounded, its entire surface marked by incised spirals like the spaces between the sutures. In addition to the spiral markings the entire surface shows fine incremental lines. Aperture elongate-ovate effuse at junction of the outer lip and the columella; posterior angle obtuse; outer lip thin; columella stout, curved, and decidedly reflected over the reenforced base, provided with a strong oblique fold opposite the obsolete umbilical chink; parietal wall covered with a thin callus. Length, 5.3; diameter, 2.6 mm. (Dall & Bartsch). Departure Bay, Vancouver Island, by Dr. C. M. Fraser.\*—Bear Bay, Peril Straits, Alaska, to Vancouver Island.

*Odostomia* (Evalea) *deliciosa* Dall & Bartsch, 1907. (Pl. 47, fig. 5, Proc. U. S. Nat. Mus., vol. 33). Shell small, elongate-conic, translucent to milk-white. Nuclear whorls small, deeply immersed in the first of the succeeding turns above which only a portion of the last

turn is visible. Post-nuclear whorls moderately rounded, very weakly roundly shouldered at the summit, separated by strongly marked sutures; a narrow band appears about the summit showing its junction with the preceding turn. Periphery and base of the last whorl inflated and well rounded. Entire surface of base and spire marked by very fine lines of growth and numerous microscopic wavy spiral striations. Aperture rather large, somewhat effuse anteriorly; posterior angle acute; outer lip thin; columella rather stout, strongly curved, and revolute, reenforced by the attenuated base, and covered with a strong fold at its insertion. This fold can be seen through the transparent shell as a quite strong lamella on the pillar of the turns. Length, 4; diameter, 1.9 mm. (Dall & Bartsch). Barkley Sound, Vancouver Island.—Vancouver Island to Monterey, Calif.

*Odostomia* (Amaura) *kennerleyi* Dall & Bartsch, 1907. (Plate 45, fig. 3; plate 5, fig. 7). Shell large, very thin, broadly conic, umbilicated, yellowish-white; marked by subobsolete, subequal, and subequally spaced spiral wrinkles, about 15 of which may be seen on the body and base of the last whorl. In addition to these wrinkles, many faint closely placed spiral and vertical striae are present. Nuclear whorls small about  $2\frac{1}{2}$ , forming a depressed spire which is deeply immersed, the axis of which is at right angles to the axis of the latter whorls. Post-nuclear whorls very wide, inflated, well rounded, faintly shouldered at the summit. Suture well marked, simple. Periphery and base of last whorl inflated, well rounded, the latter decidedly contracted and narrowly umbilicated. Aperture large, suboval, somewhat effuse anteriorly; posterior angle obtuse, outer lip thin; columella straight, obliquely inserted, revolute, not reenforced by the base, with an oblique weak fold near its insertion; parietal wall apparently without a callus. Length, 10.2; diameter, 6 mm. (Dall & Bartsch). Off Shaw Island, Wash., in 25 fathoms.\*—Nanaimo, B. C., to Monterey, Calif.

*Odostomia* (Amaura) *canfieldi* Dall, 1908. (Pl. 28, fig. 2, Bull. U. S. Nat. Mus., No. 68). Shell large, similar in form to *O. avellana*; white, shining. Nuclear whorls 3, helicoid, quite elevated, deeply immersed in the first of the succeeding whorls, having their axis at a right angle to the axis of the later whorls. Post-nuclear whorls well rounded, with a beveled shoulder at the summits. Suture well marked, simple. Periphery and base of the last whorl well rounded and inflated, the latter somewhat elongated. Aperture subovate, somewhat effuse anteriorly; posterior angle acute; outer lip thin at the edge, thick within; columella curved and somewhat revolute, having a

prominent oblique fold near its insertion; parietal wall covered by a thin callus. Length, 9.6; diameter, 5.1 mm. (Dall). Nanaimo, B. C.—Nanaimo and Barkley Sound, B. C., to San Diego, Calif.

*Odostomia* (*Amaura*) *talpa* Dall and Bartsch, 1909. (Pl. 27, fig. 9, Bull. U. S. Nat. Mus., No. 68). Shell stout, rough, very broadly conic, narrowly umbilicated. Nuclear whorls small, deeply obliquely immersed in the first post-nuclear turn. Post-nuclear whorls with quite strong, concavely shouldered summits, the rest well rounded (usually showing decided erosion marks which coincide largely with the lines of growth). The parts bearing the original surface show traces of exceedingly fine spiral striations. Periphery and base of the last whorl rather inflated, well rounded, the latter narrowly umbilicated, marked like the spire. Aperture broadly oval, posterior angle obtuse; outer lip rather thick, columella stout, thick, somewhat flexuose and reflected, provided with a strong fold a little anterior to the umbilicus; parietal wall covered with a thin callus. (Dall & Bartsch). Length 8, diameter 3.8 mm. Turn Island, Friday Harbor, Wash., at roots of eelgrass.\*—Mole Harbor, Alaska, to Friday Harbor, Wash.

*Odostomia* (*Amaura*) *satura* Carpenter, 1865. (Pl. 27, fig. 1, Bull. U. S. Nat. Mus., No. 68). Shell of medium size, broadly conic, white. Nuclear whorls at least 2, forming a depressed spire, the axis of which is almost at right angle to the axis of the latter whorls, and which is deeply, somewhat obliquely immersed in the first post-nuclear turn. Post-nuclear whorls moderately well rounded, faintly shouldered at the summit, marked all over by irregular rough, low, tumescence, which simulate obsolete vertical ribs. Sutures simple, well marked. Periphery of the last whorl well rounded. Base quite short, decidedly rounded, and umbilicated. Umbilicus partly covered by the revolute columella. Aperture large, very broadly oval, somewhat effuse anteriorly; posterior angle obtuse; outer lip thick; columella moderately strong, oblique, decidedly curved, with a decided oblique fold, situated considerably anterior to its insertion; parietal wall covered by a fairly thick callus. Length, 6.4; diameter, 3.5 mm. (Bartsch).—Known only from Neah Bay, Wash.

*Odostomia* (*Amaura*) *engbergi* Bartsch, 1920. Shell elongate ovate, yellow, a little paler toward the tip. Nuclear whorls eroded in all the specimens seen. Post-nuclear whorls narrowly tabulatedly shouldered at the summit, quite strongly rounded, marked by very fine slightly slanting lines of growth and equally fine spiral striations, the combination, when viewed under the microscope, giving to the surface

a cloth-like texture. Suture strongly marked. Periphery of the last whorl inflated, strongly rounded. Base strongly rounded. Aperture narrowly ovate; posterior angle very obtuse; outer lip thin; inner lip short, very oblique, somewhat sinuous, reflected over the base and appressed to it except at the extreme tip, which alone is free; a strong fold is present on the inner lip a little anterior to its insertion; parietal wall covered by a thin callus. Altitude, 7; diameter, 3.4 mm. (Bartsch). San Juan Island, Wash.\*—Puget Sound.

*Odostomia* (Amaura) *grippiana* Bartsch, 1912. (Pl. 38, fig. 11, Proc. U. S. Nat. Mus., vol. 42). Shell large, umbilicated, yellowish-white. Nuclear whorls decollated. Post-nuclear whorls decidedly, slopingly, tabulatedly shouldered at the summit, otherwise moderately rounded; marked by fine incremental lines and numerous, equal and equally spaced, slender, wavy, spiral threads, of which 6 occur upon the shoulder, and about 40 between the shoulder and the suture. Periphery and the moderately long base of the last whorl well rounded, marked like the spire. Aperture moderately large, ear-shaped; posterior angle obtuse; inner lip moderately long, stout, curved, somewhat reflected, provided with a strong fold a little anterior to its insertion; parietal wall glazed with a thin callus. Length, 7.5; diameter, 0.4 mm. (Bartsch).—Known only from Nanaimo, B. C.

*Odostomia* (Amaura) *gouldi* (Carpenter) Dall & Bartsch, 1905. (Pl. 27, fig. 2, Bull. U. S. Nat. Mus., No. 68). Shell of medium size, elongate-conic, yellowish-white, the exterior surface marked by irregular tumescences, giving it a much worn appearance. Nuclear whorls 3, deeply immersed, having their axis at about a right angle to the axis of the succeeding turns. Post-nuclear whorls moderately well rounded, faintly shouldered at the summit. Sutures simple, well marked. Periphery and base of the last whorl well rounded, the latter somewhat elongated. Umbilicus faint. Aperture quite large, pyriform, posterior angle obtuse, outer lip moderately thick, columella very oblique, fairly strong, revolute, with a strong fold somewhat anterior to its insertion; parietal wall covered with a fairly strong callus. Length, 6.1; diameter, 3.1 mm. (Dall & Bartsch).—Known only from Neah Bay, Wash.

*Odostomia* (Amaura) *avellana* Carpenter, 1865. (Pl. 28, fig. 3, Bull. U. S. Nat. Mus., No. 68). Shell large, elongate-conic, yellowish to milk-white. Nuclear whorls deeply vertically immersed; only part of the last volution is visible when viewed from above, their axis evidently being at right angle to the axis of the later whorls. Post-

nuclear whorls increasing rapidly in size, early ones well rounded, later ones less so, their summits being closely appressed to the preceding whorl. Suture well impressed, simple. Periphery and base of the last whorl well rounded, the latter somewhat elongated. Aperture large, ovate, somewhat effuse anteriorly, milk-white within; posterior angle acute; outer lip thin at the edge, thick within; columella short and curved; reenforced partly by the attenuated base, having a strong oblique fold at its insertion; parietal wall covered by a moderately strong callus. Length, 8.3; diameter, 4.3 mm. (Bartsch).—Known only from Neah Bay, Wash.

*Odostomia* (Amaura) *nuciformis* Carpenter, 1865. (Pl. 28, fig. 1, Bull. U. S. Nat. Mus., No. 68). Shell large, shortly ovate, yellowish to milk-white. Nuclear whorls deeply immersed; only half of the last turn is seen in tilted position when viewed from above. Post-nuclear whorls increasing rapidly in size, well rounded, having their summits closely appressed to the preceding whorl. Suture moderately well impressed. Periphery and base of the last whorl well rounded. Aperture rather large, ovate, white within; posterior angle acute; outer lip moderately thin at the edge, thicker within; columella short, strongly curved, with a strong, oblique fold at its insertion; reenforced by the attenuated base; parietal wall covered by a thin callus. Length, 7.7; diameter, 4.4 mm. (Dall & Bartsch).—Known only from Neah Bay, Wash.

*Odostomia* (Amaura) *sanjuanensis* Bartsch, 1920. Shell elongate ovate, wax-yellow. Nuclear whorls decollated. Post-nuclear whorls narrowly tabulatedly shouldered, moderately rounded, marked by regular retractorily slanting lines of growth and fine spiral striations which give to the surface a cloth-like texture when subjected to high magnification. In addition to this sculpture, the surface of the shell is marked by strong incremental lines and more or less irregular and irregularly distributed spiral threads, which produce a malleated pattern. Suture strongly marked. Periphery of the last whorl well rounded. Base moderately long, well rounded, marked like the spire. Aperture obliquely ovate; posterior angle obtuse; outer lip thin; inner lip very obliquely retractorily slanting, somewhat flexuose and provided with a strong fold at its insertion; parietal wall covered by a thin callus. Altitude, 7.2; diameter, 3.5 mm. (Bartsch). Off San Juan Island, Wash.\*—Puget Sound.

*Odostomia* (Amaura) *washingtonia* Bartsch, 1920. Shell moderately large, broadly elongate conic, pale horn colored. Nuclear whorls too eroded to permit of description. Postnuclear whorls

strongly tabulatedly shouldered at the summit, moderately rounded, marked by decidedly retractorily slanting lines of growth and numerous very finely incised spiral striations. Sutures conspicuously marked by the tabulated summit. Periphery of the last whorl inflated, strongly rounded. Base short, inflated and strongly rounded, marked like the spire. Aperture rather large, almost subquadrate, slightly oblique; posterior angle obtuse; outer lip thin; inner lip flexuous, reflected over the base, but not appressed, the axis being decidedly protractorily slanting. A strong columella fold is present at the umbilical chink. Parietal wall covered by a thick callus. Altitude, 8.7; greatest diameter, 4.2 mm. (Bartsch). San Juan Island, Wash.\*—Puget Sound.

### Family CYMATIDAE

ARGOBUCCINUM Moersch, 1852

Spire elevated, canal short, posterior channel wanting. (Tryon S. S. Conch.)

*Argobuccinum oregonense* Redfield, 1848. (Plate 15, figs. 1, 3). Shell oblong-ovate, thin, ventricose, whorls rounded, longitudinally ribbed, peculiarly latticed with narrow transverse ridges arranged 2 and 2; white, covered with a tufted bristly epidermis. Length 120, diameter 60 mm. (Conch. Iconica). Off San Juan Island, Wash., on shore and in 15-20 fathoms.\*—Bering Sea to off San Nicolas Island, Calif, and Japan.

A variety secured at Departure Bay, Vancouver Island, by Rev. G. W. Taylor, is plate 15, fig. 2.

### Family TRIFORIDAE

TRIFORA (Deshayes) Blainville, 1828

Shell sinistral, sculptured, granular; whorls numerous, terminating below in a small aperture, with tubular anterior canal; opposite this canal is sometimes a second one upon a varix, marking the position of a former aperture. Operculum orbicular, few-whorled. (Tryon S. S. Conch.)

*Trifora carpenteri* Bartsch, 1907. (Pl. 16, fig. 4, Proc. U. S. Nat. Mus., vol. 33). Shell elongate-conic, almost cylindric, bleached, white. (Early whorls decollated). Later turns ornamented by 3 spiral ridges, of which the posterior one is a little more strongly developed than the other 2 and forms the summit of the whorls. The other 2 spiral ridges are equal and equally spaced. In addition to

the spiral ridges, the whorls are marked by axial ribs, about as strong as the spiral ridges, the intersection of the ribs and ridges forming strong tubercles, while the spaces inclosed between them appear as deeply impressed square pits. There appear to be about 22 tubercles upon all whorls. The sutures appear as broad, deep channels, which are crossed by the extensions of the axial ribs. On the last 3 turns the posterior edge of the peripheral keel is apparent in the suture. In addition to the above sculpture, the entire surface of the spire is marked with microscopic lines of growth and equally fine spiral striations. Periphery of the last turn marked by a strong spiral keel. Base marked by 2 strong rounded keels, of which the posterior one is separated about as far from the peripheral keel as that is separated from the suprapерipheral one. The anterior keel of the base is situated on the columella and is separated by a little wider and deeper channel from the posterior keel than that is from its posterior neighbor; anteriorly it is limited by a feebly impressed groove. The channels of the base are crossed by weak continuations of the axial riblets. Aperture ovate, strongly channelled anteriorly and moderately so posteriorly; columella short, stout, and twisted; covered by a strong callus which also extends over the parietal wall. Length 7.2, diameter 2.2 mm.—Known only from Neah Bay, Wash.

### Family CERITHIOPSIDAE

CERITHIOPSIS Forbes & Hanley, 1819

Shell like *Bittium*; nuclear whorls sinistral. Operculum pointed, nucleus apical. (Tryon S. S. Conch.)

*Cerithiopsis stephensae* Bartsch, 1909. (Pl. 38, fig. 7, Proc. U. S. Nat. Mus., vol. 40). Shell elongate-conic, chocolate brown. (Nuclear whorls decollated in all specimens seen). Post-nuclear whorls well rounded, ornamented spirally by 4 keels between the sutures, of which the posterior 3 are strong and tuberculate, the fourth smooth and slender. Axially the whorls are marked by irregular ribs, the junctions of which with the spiral keels form tubercles. The posterior row of tubercles is at the summit and is the weakest, the individuals appearing as rounded knobs. The second is on the middle of the whorl. This and the first, which is immediately above the peripheral sulcus, have their tubercles of about equal strength. On these 2 keels the tubercles slope gently anteriorly and very abruptly posteriorly. The peripheral sulcus and the other 2 sulci are equally strong and wide. All are crossed by the ribs, which, however, do not extend over the base. Both spiral cords and ribs are crossed by strong



incremental lines. Sutures constricted. Periphery of the last whorl marked by a deep channel. Base well rounded, rather short, marked by strong incremental lines and a few very fine spiral striations. The summit of the succeeding whorl drops a little below the peripheral sulcus in all the whorls of the spire and allows a narrow margin of the smooth base to appear as a cord in the suture. Aperture ovate, with a strong anterior sinus, outer lip thin, showing the external sculpture within; columella stout, twisted and curved, having a weak basal fasciole at its insertion. Length, 9; diameter, 2.1 mm. (Bartsch.) Off O'Neal Island, San Juan county, Wash., in 25 fathoms.\*—Bear Bay, Baranoff Island, Alaska, to Puget Sound.

*Cerithiopsis onealensis* Bartsch, 1921. Shell elongate conic, pale chestnut brown. Nuclear whorls decollated. Postnuclear whorls moderately rounded, slightly overhanging, crossed by very strong, broad, rounded, slightly protractively slanting axial ribs, of which 16 occur upon the first turns, 18 upon the fifth and upon the last. Intercostal spaces about half as wide as the ribs. In addition to the axial ribs the whorls are crossed by 3 strong spiral cords, of which the one at the summit is a little less strong than the other 2. The junction of the axial ribs and spiral cords forms very prominent tubercles. Those on the cord near the summit are well rounded. Those on the median cord truncated posteriorly, and almost truncated anteriorly while those on the cord above the suture are abruptly truncated posteriorly and slope moderately, gently anteriorly. On the last whorl, where the ribs are much more crowded, the tubercles have an oblong outline, and are about equal on all 3 cords, their long axis coinciding with the axis of the shell. The pits enclosed by the spiral cords and axial ribs are well rounded on all the whorls. Suture strongly impressed. Periphery of the last whorl marked by a sulcus about as broad as that separating the median from the supersutural cord on the spire. Base short, well rounded, marked by feeble continuation of the axial ribs, which lend it a roughened aspect, and a single spiral thread, which encircles the base at the insertion of the columella. Aperture decidedly channeled anteriorly; posterior angle obtuse; outer lip thin, showing the external sculpture within, sinuous at the edge; inner lip sigmoid, reflected over and appressed to the columella. Length, 5.1; diameter, 1.9 mm. (Bartsch).—Known only from near O'Neal Island, San Juan County, Wash., in 25 fathoms.

*Cerithiopsis signa*, Bartsch, 1921. Shell elongate conic, pale brown. First half postnuclear whorl smooth, the next  $1\frac{1}{2}$  well rounded and marked by rather distantly spaced, almost vertical axial

ribs. Postnuclear whorls appressed at the summit, marked by strong, rounded almost vertical axial ribs, of which 18 occur upon the first, 14 upon the second to sixth, 16 upon the seventh, and 18 upon the last turn. The spiral sculpture consists of 3 strong, equally spaced cords, which are crossed by strong axial ribs. The intersection of the axial ribs and the spiral cords form strong tubercles, which are truncated on their posterior margin, and slope gently anteriorly in all 3 groups. The spaces enclosed between the cords and the ribs are elongated pits which have their long axis coinciding with the spiral sculpture. In addition to this, the entire surface of the spire is marked by fine axial lines of growth and closely spaced spiral striations. Suture strongly impressed. Periphery of the last whorl rendered angulated by a keel. Base short, slightly convex at the insertion of the columella, marked by fine lines of growth and very fine spiral striations, and a slender spiral thread at the insertion of the columella. Aperture subquadrate; decidedly channeled anteriorly; posterior angle obtuse; outer lip rendered sinuous by the spiral cords; inner lip sigmoid, reflected over and appressed to the columella. Length, 5.5; diameter, 2.7 mm. (Bartsch). Off O'Neal Island, near Friday Harbor, Wash., in 25 fathoms.\*—Nanaimo, B. C., to Puget Sound.

*Cerithiopsis willetti* Bartsch, 1921. Shell large, robust, elongate, conic, pale brown. All but the last nuclear whorl decollated. This shows, however, that the species belongs to the subgenus *Cerithiopsina*. Postnuclear whorls crossed by very strong, almost sublamellar, rather coarse, rounded, protractively slanting axial ribs, of which 16 occur upon the first to fifth, 18 upon the sixth, 20 upon the seventh, and 24 upon the last turn. Intercoastal spaces about two thirds as wide as the ribs. In addition to the axial ribs there are 3 strong spiral cords, of which the first is about as far anterior to the summit of the whorls as it is distant from its median neighbor. The first of these spiral cords is a little less strongly developed on the earlier whorls than on the succeeding turns, where it almost equals the other 2. The junction of the axial rib and the spiral cords forms strong tubercles, of which those on the cord at the summit are well rounded, while those on the median cord are truncated posteriorly and slope gently anteriorly. The same is true of the supra-sutural cord. On the last whorl, however, the tubercles are more elongated and the truncation at the anterior margin is less pronounced, the long axis of the tubercles coinciding with the axis of the shell. The spaces enclosed between the axial ribs and spiral cords are well rounded pits. The summit of the whorls falls a little anterior to the peripheral

cord, and lets this appear as a narrow, smooth, sinuous thread in the somewhat constricted suture. Periphery of the last whorl marked by a strong cord, which constitutes the termination of the axial ribs. Base short and rounded, but concave at the junction with the columella. The junction of the columella and the base is marked by a slender spiral cord. Aperture broadly oval, decidedly channeled anteriorly; posterior angle obtuse; outer lip thin, rendered sinuous by the external sculpture, which is also seen within the aperture by transmitted light; inner lip reflected over and appressed to the columella. Length, 7.5; diameter, 2.5 mm. (Bartsch). San Juan Island, Wash.\*—Forrester Island, Alaska, to Puget Sound.

*Cerithiopsis fraseri* Bartsch, 1921. Shell elongate conic, chestnut brown. Nuclear whorls decollated. Post-nuclear whorls almost flattened, marked by moderately strong, rounded, slightly retractively slanting axial ribs, of which 18 occur upon the first, 16 upon the second to fourth, 18 upon the fifth, 20 upon the sixth and seventh, 26 upon the eighth and the last whorl. Intercoastal spaces about half as wide as the ribs. The spiral sculpture consists of 3 strong cords, of which the first, at the summit, is a little less strong on the early whorls than the other 2, but on the last 2 whorls it equals the other 2 cords. The intersection of the axial ribs and spiral cords forms strong tubercles rounded on the first cord, slightly truncated posteriorly on the median cord, and strongly rounded anteriorly and strongly truncated on the third cord posteriorly, and gently sloping anteriorly. The spaces enclosed between the axial ribs and spiral cords are well rounded pits. Suture strongly impressed, the extreme appressed portion of the summit appearing as a slender sinuous spiral thread. Periphery of the last whorl marked by a sulcus about half as wide as that separating the median from the third cord. Base short, well rounded, marked by the feeble continuations of the axial ribs which extend more or less threadlike over the base, and 2 strongly impressed spiral lines on the posterior fourth of the base. The space separating the first from the second of these spiral lines is about as wide as that separating the first from the peripheral sulcus. There is no spiral cord at the insertion of the columella. Aperture decidedly channeled anteriorly; posterior angle obtuse; outer lip thin, rendered wavy at the edge by the external sculpture which is visible through the substance of the shell; inner lip decidedly sinuous, reflected over and appressed to the columella; partial wall provided with a thin callus. Length, 6.5; diameter, 2.3 mm. (Bartsch). Clayoquot, B. C.\*—Queen Charlotte Islands to Victoria, B. C.

*Cerithiopsis charlottensis* Bartsch, 1917. (Pl. 46, figs. 9, 11, Proc. U. S. Nat. Mus., vol. 56). Shell elongate conic, pale brown. Nuclear whorls strongly rounded, 3, forming a slender very elevated spire, smooth. Postnuclear whorls well rounded, appressed at the summit, marked by rather strong, almost vertical axial ribs of which 14 occur upon the first 4 turns, 16 upon the fifth, 18 upon the sixth, and 20 upon the penultimate whorl. Intercostal spaces a little wider than the ribs. The spiral sculpture consists of 3 strong cords, of which the one at the summit is a little less strong than the other 2. The junction of the spiral cords and the axial ribs form strong tubercles, those on the cord at the summit are well rounded, while those of the median cord are truncated anteriorly and posteriorly. The tubercles of the third cord are truncated posteriorly and sloped gently anteriorly. The spaces inclosed between the spiral cords and the axial ribs are well-rounded pits. Suture moderately constricted. Periphery of the last whorl marked by a spiral groove, which equals in strength and width the groove that separates the median from the third cord on the spire. Base short, well rounded, smooth, excepting the exceedingly fine incremental lines and microscopic spiral striations which are also present on the spire and a very slender basal fasciole which surrounds the insertion of the inner lip. Aperture decidedly channeled anteriorly; posterior angle obtuse; outer lip thin, showing the external sculpture within, decidedly sinuous at the edge; inner lip rendered decidedly flexuose; parietal wall covered by a thin callus. Length 5, diameter 1.7 mm. (Bartsch). Nanaimo, B. C.\*—Queen Charlotte Islands to Puget Sound.

*Cerithiopsis stejnegeri dina* Bartsch, 1911. (Pl. 2, fig. 4, Proc. U. S. Nat. Mus., vol. 7; also pl. 40, fig. 3, vol. 40). This is the southern representative of *C. stejnegeri* differing from the species in having the sculpture much more strongly pronounced and in being larger. Length 7, diameter 2.6 mm. (Bartsch). Victoria, B. C., by Dr. C. F. Newcombe.\*—Sitka, Alaska, to Strait of Fuca.

*Cerithiopsis columna* Carpenter, 1864. (Pl. 38, fig. 9, Proc. U. S. Nat. Mus., vol. 40). Shell elongate-conic, light chestnut brown. (Early whorls decollated). Succeeding turns very slightly rounded, marked by 3 tuberculate spiral keels, of which one is at the summit, another a little above the periphery, and a third a little nearer the posterior than its supra-sutural neighbor. These keels are separated by spiral grooves, which are only about one-third as wide as the keels. In addition to the spiral keels, the whorls are marked by almost vertical axial ribs, which are about two-thirds as strong as the

spiral cords and very closely spaced. Of these, 16 occur upon the second and third, 18 upon the fourth, 22 upon the fifth and sixth, 24 upon the seventh, 26 upon the eighth, and 32 upon the penultimate turn. The narrow spaces inclosed between the ribs and spiral cords appear as small, well impressed, rounded pits. Suture moderately constricted, showing the posterior edge of the first basal keel in the early whorls. Periphery of the last whorl marked by a sulcus as wide as those that separate the keels on the spire, and the continuation of the axial ribs. Base short, well rounded, marked with 3 slender spiral keels which are situated on the posterior two-thirds and separated by shallow channels. The first of these is crossed by slender continuations of the axial ribs. The space immediately about the base of the columella is free of sculpture excepting fine, incremental lines. Aperture subquadrate, decidedly channeled anteriorly; posterior angle acute; outer lip rendered sinuous by external sculpture; columella very broad at base, stout, somewhat twisted and curved and the edge reflected. Length, 9.2; diameter, 2.6 mm. (Bartsch). Off San Juan Island.\*—Vancouver Island to Monterey Bay, Calif.

*Cerithiopsis paramoëa* Bartsch, 1911. (Pl. 38, fig. 4, Proc. U. S. Nat. Mus., vol. 40). Shell moderately large, broadly elongate-conic, brown. (Nuclear whorls gone). Post-nuclear whorls appressed at the summit, ornamented with 3 nodulose, spiral cords which are about as wide as the spaces that separate them. The first of these is at the summit, the third is on the anterior fourth between the sutures, while the second is halfway between the 2. In addition to the spiral cords, the whorls are marked by axial ribs almost equalling the spiral cords in strength; of these ribs, 16 occur upon the first and second, 18 upon the third, 20 upon the fourth, 22 upon the fifth, and 32 upon the penultimate turn. The junctions of the axial ribs and spiral cords form nodules which on the early whorls are well rounded and on the last elongate, their long axes corresponding with the axial sculpture. The spaces inclosed between them are well rounded pits. Sutures moderately impressed, showing the posterior edge of the first basal cord. Periphery of the last whorl marked by a sulcus almost as wide as that separating the supraperipheral from the median cord, and, like it, crossed by the continuations of the axial ribs. Base well rounded, smooth except for the feeble cord immediately below the peripheral sulcus. Aperture irregularly oval, decidedly channeled anteriorly; posterior angle obtuse; outer lip rendered somewhat sinuous by the external sculpture; columella short, curved, with the free edge re-

flected; partial wall glazed with a thin callus. Length, 6.3; diameter, 2.1 mm. (Bartsch). Off O'Neal Island, Wash., in 25 fathoms.\*—Puget Sound to Neah Bay, Wash.

### Family CERITHIIDAE

#### *BITTIUM* (Leach) Gray, 1847

Shell elevated, with numerous granular whorls, and irregular varices; anterior canal short, not recurved; inner lip simple; outer lip not reflected, usually with an exterior rib. Operculum 4-whorled. (Tryon S. S. Conch.)

*Bittium* (Stylidium) *eschrichtii* Middendorff, 1849. (*B. filosum*). (Pl. 11, fig. 1, Middendorff's Beitrage zu einer Malacologia Rossica, vol. 2). Shell broadly elongate-conic, rather coarse, varying in color from white to chestnut brown. The nucleus consists of a single, smooth, white whorl, well rounded. Post-nuclear whorls well rounded, marked by 4 strong, somewhat flattened, spiral keels between the sutures, which are separated by deep, strong, spiral grooves about two-thirds as wide as the keels. In addition to this spiral sculpture, the whorls are marked by numerous fine, spiral striations and fine lines of growth. Periphery of the last whorl marked by a sulcus as wide as the sulci between the keels on the spire. Base well rounded, marked by 8 equally spaced spiral cords, which grow successively weaker from the periphery to the umbilical area. In addition to these cords the base is marked by fine spiral lines and fine lines of growth. Aperture oval, somewhat effuse anteriorly; posterior angle obtuse; outer lip thin, rendered wavy by the external sculpture; columella short, very broad at base, somewhat twisted and reflected; parietal wall glazed with a thin callus. Length, 17; diameter, 5 mm. (Bartsch). Brown and San Juan Islands, Wash.; general, along shore.\*—Alaska to Puget Sound.

*Bittium* (Semibittium) *attenuatum* Carpenter, 1864. (*B. esuriens*). (Pl. 54, figs. 1, 2, 5, Proc. U. S. Nat. Mus., vol. 40). Shell elongate-conic, varying in color from plain white to brown, variously banded or maculated. Nuclear whorls 2, moderately rounded, smooth. Post-nuclear whorls slightly rounded, ornamented with weak spiral bands which are best developed on the early whorls. These spiral bands are truncated anteriorly and slope gently to the posterior boundary. The early whorls have 3 spiral bands, of which the posterior, at the summit, is less strongly developed than the other 2, which divide the remaining space between the sutures equally. On the middle whorls

the posterior keel has a tendency to become divided, while on the later turns it becomes obsolete. In addition to the spiral sculpture, the whorls are marked by poorly developed, rounded, protractive, axial ribs which render their intersections with the spiral cords nodulose. Of these ribs, 12 occur upon the third and 14 upon each of the remaining turns upon which the ribs are discernible. The spaces inclosed between the ribs and spiral bands are shallow, impressed, rectangular pits. In addition to the axial ribs, the whorls are marked by numerous fine lines of growth. Periphery of the last whorl marked by a spiral band, which is separated from the first band above the periphery by a sulcus as wide as the sulci on the spire. Base short, well rounded, marked by 6 spiral keels, of which the first below the periphery is much larger than the rest, which are subequal and subequally spaced. Aperture ovate, somewhat effuse anteriorly; posterior angle acute; outer lip thin, showing the external marking within; columella short, very broad at base, oblique, and reflected. Length, 10.2; diameter, 3 mm. (Bartsch). Neah Bay, Wash.—Forrester Island, Alaska, to San Diego, Calif.

*Bittium* (Semibittium) *attenuatum boreale* Bartsch, 1911. (Pl. 54, fig. 4, Proc. U. S. Nat. Mus., vol. 40). Shell similar to *B. attenuatum*, but in every way larger and more robust. Sculpture very much stronger than in the typical form; the tubercles well developed on the last whorl, but much weaker than in the earlier ones. Length, 10.7; diameter, 3.5 mm. (Bartsch). Barkley Sound, Vancouver Island.—Queen Charlotte Islands to Vancouver Island.

*Bittium* (Semibittium) *challissae* Bartsch, 1917. (Plate 47, fig. 5). Shell very large, white. Nucleus and early postnuclear turns decollated, those remaining slightly shouldered at the summit, weakly rounded in the middle and decidedly contracted immediately above the suture, marked by rather strong, low, well-rounded axial ribs of which 14 occur upon the second and third, 16 upon the fourth to sixth, 18 upon the seventh, and 20 upon the last turn. The spiral sculpture consists of 4 cords on the early whorls, of which the first at the summit is a little weaker than the rest. These primary cords are truncated posteriorly and slope gently anteriorly. Beginning with the fourth whorl an intercalated thread makes its appearance between all the cords and between the summit and the first cord. Suture strongly constricted. Periphery of the last whorl rendered angulated by a cord. Base short, slightly concave, marked by 5 low, broad, well rounded, obsolete cords which are subequal and subequally spaced. Aperture broadly oval, rather strongly channeled anteriorly;

posterior angle obtuse; outer lip thin rendered sinuous at the edge by the external sculpture, showing the external markings within; inner lip somewhat sinuous, rather stout, reflected over and appressed to the base; parietal wall covered by a moderately thick callus. Length, 13; diameter, 4.2 mm. (Bartsch). Known only from San Juan Island, Wash.

*Bittium* (Semibittium) *sanjuanense* Bartsch, 1917. (Plate 47, fig. 3). Shell very large, rather thin, bluish white. Nuclear whorls decollated. Postnuclear whorls almost appressed at the summit, well rounded, decidedly contracted immediately posterior to the suture, marked by strong, broad, heavy, slightly protractive axial ribs which become enfeebled toward the summit and slightly widened there. Of these ribs, 12 occur upon the second and third, 14 upon the fourth and fifth, and 16 upon the last whorl. Intercostal spaces not quite as broad as the ribs. The spiral sculpture consists of 5 cords, of which the first, which is at the summit, is very slender. The 2 succeeding this are successively a trifle stronger, while the fourth and fifth are very strong, the last being the heaviest of all. The junction of the axial ribs and the spiral cords form well-rounded, elongated nodules which have their long axis parallel with the spiral sculpture; the spaces enclosed between them are very shallow, rectangular pits. In addition to the above sculpture the entire surface of the spire and base is marked by many very slender lines of growth and exceedingly fine microscopic spiral striations, the combination of which gives the surface a somewhat clothlike texture. Suture strongly constricted; it would be channeled were it not for the fact that the peripheral keel makes its appearance above the summit of the whorl, hence removes the strongly channeled element. Periphery of the last whorl marked by strong spiral cord, which is about as far anterior to the fifth cord of the spire as that is separated from the fourth. Base very short, decidedly concave, marked by 3 slender spiral cords, of which the first is about as far anterior to the periphery as that is distant from the fifth cord on the spire. The other 2 cords are very slender, the first being at the base of the columella, while the next is a little distance posterior to it. Aperture subquadrate; quite strongly channeled anteriorly; the junction of the outer and basal lip forming almost a right angle; posterior angle obtuse; outer lip very thin, showing the external sculpture within and rendered sinuous by the external sculpture at the edge; inner lip decidedly oblique, slightly curved, slender,



reflected and appressed to the base; parietal wall covered by a thin callus. Length, 11; diameter, 3.8 mm. (Bartsch).—Known only from off San Juan Island, Wash.

*Bittium* (Semibittium) *vancouverense* Dall & Bartsch, 1910. (Plate 12, fig. 8). Shell elongate-conic, grayish-white outside and dark purplish-brown within. Nuclear whorls at least 2, apparently smooth; worn in all specimens. Post-nuclear whorls slightly rounded, ornamented with 3 strong, equal, and equally spaced, nodulose, spiral keels, of which the first is a little below the summit. The spaces separating the spiral keels are of equal width. Immediately below the third keel is a strong peripheral sulcus, which equals those between the spiral keels. In addition to the spiral sculpture, the whorls are marked by almost vertical, axial ribs which are not quite as wide as the spiral keels. These render the keels nodulose at their intersection. Of these ribs, 12 occur upon the first, 14 upon the second and third, 16 upon the fourth, 18 upon the fifth, 24 upon the sixth, and 30 upon the penultimate turn. The spaces enclosed between the spiral keels and the axial ribs are well impressed, rounded pits. All the tubercles are truncated on the posterior margin, and slope gently anteriorly. Base of the last whorl moderately long, ornamented with 7 spiral cords, of which the 2 immediately below the periphery are the strongest and broadest, while the 2 bounding the umbilical area are wider than those intervening. Sutures channeled. Aperture irregular, channeled anteriorly; posterior angle obtuse; outer lip thin, sinuous, showing the external sculpture within; columella stout, short, twisted and reflected; parietal wall glazed with a moderately thick callus. Length, 7.8; diameter, 2.7 mm. (Dall & Bartsch).—Known only from Barkley Sound, Vancouver Island.

*Bittium* (Liobittium) *munitum* Carpenter, 1864. (Pl. 53, figs. 1, 2, Proc. U. S. Nat. Mus., vol. 40). Shell elongate-conic, yellowish white. Nuclear whorls a little more than one (with the sculpture abraded in all our specimens). Post-nuclear whorls strongly shouldered at the summit, marked by 3 strong, equal and equally spaced spiral keels, which are a little wider than the spaces that separate them. In addition to the spiral keels, the whorls are marked by somewhat retractive axial ribs, of which 18 occur upon the second, 20 upon the third, 24 upon the fourth and fifth, and 28 upon the penultimate. The intersections of the axial ribs and spiral keels form strong tubercles, while the spaces between them are well impressed, rounded pits. Suture subchanneled. Periphery of the last whorl marked by a strong channel, across which the feeble continuations of the axial

ribs extend. Base moderately long, marked by 6 strong spiral cords which grow successively weaker from the periphery to the umbilical area. In addition to the above sculpture, the entire surface of the spire and base is crossed by numerous fine lines of growth and exceedingly fine, spiral striations. Aperture subquadrate, channeled anteriorly; posterior angle obtuse; outer lip rendered sinuous by the external sculpture; columella short, stout, somewhat twisted and reflected, parietal wall glazed with a thin callus. Length, 7.8; diameter, 3 mm. (Bartsch). Neah Bay, Wash.; Alert Bay, B. C.—Sitka, Alaska, to Neah Bay, Wash.

*Bittium oldroydi* Bartsch, 1911. (Pl. 51, fig. 5, Proc. U. S. Nat. Mus., vol. 40). Shell very large, chestnut brown. (Nuclear whorls decollated in all our specimens). Post-nuclear whorls moderately rounded, ornamented with 3 spiral keels, which are truncated on their posterior margin and slope gently anteriorly until they fuse with the general mass of the shell. These keels divide the space between the sutures into 4 almost equal parts, the space between the summit and the first keel being a little narrower than the rest. In addition to the spiral keels, the whorls are marked by slightly retractive axial ribs, of which 12 occur upon the second, 14 upon the third and fourth, 16 upon the fifth to seventh, 18 upon the eighth, 20 upon the ninth and tenth, and 22 upon the penultimate turn. These ribs extend from the summit to the suture. Their intersections with the spiral cords form strong, cusped nodules, which slope more abruptly anteriorly than posteriorly. The spaces inclosed between the spiral keels and the axial ribs are considerably wider than the ribs or cords and form squarish pits. Sutures strongly marked, showing a slender, smooth peripheral cord (to which the axial ribs extend) on almost all the turns. Periphery and base of the last whorl well rounded, marked by 6 well-rounded spiral cords, which grow successively weaker, and a little more closely spaced from the periphery to the umbilicus. Entire surface of spire and base crossed by numerous slender axial lines of growth. Aperture moderately large, channeled anteriorly; posterior angle obtuse; outer lip rendered sinuous by the external sculpture; columella stout, flexuose and reflected; parietal wall covered with a thick callus. Length, 13.3; diameter, 3.8 mm. (Bartsch). Destruction Island, Wash.—Destruction Island, Wash., to Lower California.

**Family TRICHOTROPIDAE**

TRICHOTROPIS Sowerby, 1829

Shell thin, turbinated, carinated, the ridges with epidermal fringes in fresh or living specimens; columella obliquely truncated. Operculum lamellar, nucleus external. (Tryon S. S. Conch.) Type *T. borealis* Gould.

*Trichotropis cancellata* Hinds, 1843. (Pl. 11, figs. 11, 12, Hind's Zool. Voyage H. M. S. *Sulphur*). Shell oblong, the spire more produced than in *T. bicarinata*; the whorls separated by a deep suture, profoundly cancellated; many-keeled, and furnished on the lines of the striae of increase with numerous short bristles at regular intervals. The aperture is rounded, and truncated at the base; the canal so short as scarcely to exist. Umbilicus small and somewhat concealed by the inner lip, which is slightly developed. (Hinds). Length 27, diameter 14 mm. Off San Juan Island, Wash., in 15-25 fathoms.\*—Bering Sea to Oreg.

**Family CAECIDAE**

MICRANELLUM Bartsch, 1920

Surface of the shell marked by closely spaced, slender, axial annulations; operculum thin, corneous, concave. (Bartsch). Type *Caecum crebricinctum* Carpenter.

*Micranellum barkleyense* Bartsch, MS.—Barkley Sound, Vancouver Island, B. C.\*

*Micranellum oregonense* Bartsch, MS.—Departure Bay, Vancouver Island, B. C.\*

FARTULUM Carpenter, 1858

Shell smooth, excepting microscopic incremental lines. (Bartsch). Type *Caecum laevis* C. B. Adams.

*Fartulum occidentale* Bartsch, MS. Departure Bay, Vancouver Island, B. C.; Olga, Orcas Island, Wash.\*—Gulf of Georgia to Lower California.

**Family VERMETIDAE**

BIVONIA Gray, 1850

Shell affixed, mostly spiral; aperture contracted, circular; with spiral, interruptedly nodulose lirae, and a median elevated line;

columella smooth. Operculum small, rudimentary. (Tryon S. S. Conch.)

*Bivonia compacta* Carpenter, 1864. B. testa satis magna, saepe solitaria, purpureo-fusca, spiraliter plerumque satis regulariter contorta, obsoletin cancellat seu sculpture fere evanida; testis tenacissime adhaerente. Shell has the aspect of *Petalochonchus macrophragma* on a large scale, but is entirely destitute of internal laminae. One specimen had a faint columellar thread for 2 whorls only. Operculum normal, with thin edge, dark red. (Carpenter). Vancouver Island.—Vancouver Island to San Pedro, Calif.; Peru.

ALITES Carpenter, 1857

(Operculum slightly concave, multispiral, often irregularly formed. (H. & A. Adams).)

*Alites squamigerus pernatus* Moersch, 1856. Solitary, laterally attached, longitudinal lirae rather distant, compressed, nodosely serrated, alternately smaller, the interstices striate; whitish, or yellowish, with angulated (pennate) incremental striae, which are occasionally chestnut-colored. (Tryon Manual Conch.) San Juan Island, Wash.\*—Puget Sound to Peru.

PETALOCONCHUS Lea, 1843

Shell with 2 internal ridges running spirally along the columella, becoming obsolete near the apex and aperture. (Tryon, S. S. Conch.)

*Petalochonchus complicatus* Dall, 1908. (Plate 5, fig. 9). Coil at first closely wound and more or less obliquely bent in conformity with its situs, the first few turns with a subcircular section, very irregularly disposed, those following with a roughly hexagonal section closely coiled around a barely perforate axis, closely coherent to each other and running up to 20 or more in number, after which the tube once more becomes erect, with circular section, and a slight dextral twist; aperture circular, often with a series of internal concentric lamellae as if the animal had attempted to contract the opening by secreting a succession of smaller tubes within it; sculpture irregular; apart from incremental lines, there is a longitudinal, irregular, but tolerably smooth ridge on the middle of the exposed whorl with strong wrinkles at right angles to it on each side but not crossing it. At resting stages there are sometimes angular projections of the margin of the temporary aperture; the wrinkles are sometimes reticulated by longitudinal subequal threads, which may be entirely wanting on other parts of the same individual; the erect portion is nearly smooth except for lines of

growth; the color is a pale ferruginous brown; the length of the coiled portion may be about 16, and of the erect part 27 mm., the tube with a diameter at the aperture of 2.3 mm. There is one internal basal lamella and a smaller one projecting from the axial wall at about right angles to and a little above the former. (Dall). Puget Sound.\*—Puget Sound to Panama.

### Family TURRITELLIDAE

#### TACHYRHYNCHUS Moersch, 1868

Shell like a small Turritella, the whorls of the spire grooved across, and rounded; sculptured by spiral and longitudinal lines. Aperture oval, slightly produced in front into a rudimentary channel; lip sharp.

*Tachyrhynchus lacteolus* Carpenter, 1865. (Plate 5, fig. 8). May be a local var. of the circumpolar *T. lactea*, with altered sculpture distinct, teste Cuming. (Carpenter). Roche Harbor, Wash., in 3-4 fathoms.\*—Chignik Bay, Alaska, to Lower California.

*Tachyrhynchus reticulatus* Mighels, 1842. (Pl. 4, fig. 19, Boston Journ. Nat. Hist., vol. 4). Shell turreted, very slender, of a dingy white or ash color; whorls 11 to 12, distinctly though somewhat irregularly plicate longitudinally, with from 3 to 5 delicate, impressed, revolving striae on the 5 lower whorls; from and above the fifth whorl the transverse striae gradually diminish in number until they wholly disappear on the upper 2 or 3 whorls. The whole surface of the shell has a reticulated appearance. Suture well impressed; aperture sub-orbicular; labrum thin; operculum horny. Length, 0.07 inch; breadth, 0.02 inch. (Mighels). B. C.—Arctic Alaska to B. C.; Greenland.

### Family LITTORINIDAE

#### LITTORINA Ferussac, 1822

Shell turbinated, thick, pointed, few-whorled; aperture rounded, outer lip acute; columella rather flattened, imperforate. Operculum paucispiral.

*Littorina* (Melarhaphe) *scutulata* Gould, 1849. (Pl. 45, figs. 98-100, Tryon & Pilsbry's Manual Conch., vol. 9). Shell small, ovate-conic, inelegant, usually eroded and dead at the surface, of a chestnut or dusky leaden hue, sparsely and obscurely tessellated with whitish; with a few obsolete revolving striae; whorls 5, convex, the last ventricose, rarely with the vestige of an angle; aperture not quite half the

length of shell, broad-ovate; lip sharp and pale; columella flattened at base, which is somewhat expanded; interior livid. (Gould). Length 15, diameter 10 mm. General on the islands of San Juan County, Wash.—Puget Sound to Turtle Bay, Lower California, and Socorro Island off Mex.

*Littorina* (*Littorivaga*) *sitchana* Philippi, 1845. (Pl. 41, fig. 90, Tryon & Pilsbry's Manual Conch., vol. 9). Shell subglobose, moderately solid, strongly spirally ridged, usually with subequal intervening furrows; dark chocolate color, often with a broad white peripheral band, interior chocolate. Length 15-18 mm. (Tryon Manual Conch.) General along shore.\*—Bering Sea to Puget Sound.

*Littorina* (*Littorivaga*) *planaxis* Philippi, 1847. (Pl. 4, fig. 16, Philippi's Abbild. und Beschreib. neue oder wenig gekannte Conch.) Whorls convex, rapidly increasing, smooth or very minutely spirally striate, light chocolate color, shining, under a thin olivaceous epidermis, speckled and spotted irregularly with white, interior chocolate color with a white band near the base; columella broadly excavated, yellowish brown. Length 8 mm. (Tryon Manual Conch.) Brown Island, San Juan County, Wash.\*—Puget Sound to Magdalena Bay, Lower Calif.; Socorro and Guadeloupe Islands, Mex.

*Littorina* (*Littorivaga*) *rudis* Donovan, 1800. (Pl. 33, fig. 1, Donovan's British Shells, vol. 1). Shell solid, rarely ridged; whorls rounded, spire acute, more or less short. Mouth small, more or less rounded, not contracted above, but lessened at the base by the broad confluence of the pillar and outer lip, which latter is rather more arched above than below, and joins the body at nearly right angles. Base generally a little produced. (F. & H. British Moll.) Puget Sound.—Aleutian Islands to Puget Sound; Atlantic.

## Family LACUNIDAE

### LACUNA Turton, 1827

Shell turbinated or globular, thin, covered by an epidermis; aperture semilunar, columella flattened with a parallel groove behind it ending in the umbilicus, lip sharp, arcuated. Operculum paucispiral. (Tryon Manual Conch.)

*Lacuna porrecta* Carpenter, 1864. (Pl. 50, fig. 55, Tryon & Pilsbry's Manual Conch., vol. 9; also pl. 14, fig. 2, Bull. U. S. Nat Mus., No. 112). Larger than *L. puteola*, with more developed spire, body whorl slopingly expanded, effuse below, thinly spirally striate upon the

thin olivaceous yellow or light brown epidermis, sometimes with a pale band under the obtusely angulated periphery. Length 13 mm. (Tryon Manual Conch.) Victoria, B. C.—Commander Islands, Bering Sea, to San Diego, Calif.

*Lacuna porrecta effusa* Carpenter, 1864. (Pl. 50, fig. 56, Tryon & Pilsbry's Manual Conch., vol. 9). Larger, more effuse, whorls more tumid with well impressed suture. Length 77 mm. (Tryon Manual Conch.) Strait of Fuca.—Strait of Fuca to San Francisco, Calif.

*Lacuna porrecta exaequata* Carpenter, 1864. (Pl. 50, fig. 57, Tryon & Pilsbry's Manual Conch., vol. 9). Whorls flattened, suture scarcely impressed. Length 12.5 mm. (Tryon Manual Conch.)—Known only from Neah Bay, Wash.

*Lacuna divaricata* Fabricius, 1780. (Pl. 50, fig. 75, Tryon & Pilsbry's Manual Conch., vol. 9). Obliquely conical, periphery obtusely angulated, somewhat thin, translucent and glossy, with slight, numerous spiral striae; white, yellowish or yellowish brown often with 4 brown bands of varying width, sometimes confluent into one band, and so disposed as to exhibit a white band just below the suture. Length 11 mm. (Tryon Manual Conch.) San Juan and Orcas Islands, Wash.; along shore.\*—Norton Sound, Alaska, to Santa Barbara, Calif.; Northern Europe; Greenland.

*Lacuna solidula* Loven, 1846. (Pl. 50, fig. 69, Tryon & Pilsbry's Manual Conch., vol. 9). Shell small, turritid, thin; spire elevated, subacuate; whorls 4, rounded, ornamented with fine oblique incremental lines; suture deeply impressed, distinct; aperture large, ovate; outer lip thin; inner lip sharp, effuse, incrustated; small umbilical chink. Long, 10; lat., 6.2 mm. (Arnold). Olga, Orcas Island, Wash.\*—Puget Sound, Wash., to San Diego, Calif.; Atlantic.

*Lacuna variegata* Carpenter, 1864. (? Pl. 50, fig. 64, Tryon & Pilsbry's Manual Conch., vol. 9). Thin, expanded in front, periphery rounded or obtusely angulated, smooth, polished, fulvous, irregularly strigate with chestnut, with frequently a peripheral band of white spots, and sometimes another below the suture. Length, 7.5 mm. (Tryon Manual Conch.) False Bay, San Juan Island, Wash.\*—Puget Sound to Monterey, Calif.

*Lacuna unifasciata* Carpenter, 1856. (Pl. 50, fig. 74, Tryon & Pilsbry's Manual Conch., vol. 9). Small, glossy, generally with a colored keel, the band sometimes broken up into dots. Length, 4 mm.

(Tryon Manual Conch.) San Juan Island, Wash.\*—Puget Sound to Magdalena Bay, Lower California.

*Lacuna marmorata olla* Dall, 1918. A variety is more elevated and acute, with a more pronounced keel and narrower umbilical groove, which may take the name *olla*. (Dall). False Bay, San Juan Island, Wash.\*—Alaska to San Diego, Calif.

*Lacuna carinata* Gould, 1848. Shell small, thin, ovate, covered with a greenish straw-colored epidermis, which, under the magnifier, is found to be marked with numerous, crowded, undulating, revolving striae; whorls 5, ventricose, the last one having a raised thread-like carina at the periphery; aperture half the length of the shell, semi-circular; canal of the columella semicylindrical, extending to the base; a delicate layer of callus on the penultimate whorl. Very much like the dark variety of *L. vincta* of the Atlantic shores in color and marking, but it is less elongated. Our shell occasionally has the last whorl perceptibly angular, but never with the filiform carina. Length three-tenths of an inch; breadth one-fifth of an inch. (Gould). Olga, Orcas Island, Wash., by C. C. Engberg.—Puget Sound to San Pedro, Calif.

### Family FOSSARIDAE

*ISELICA* Dall, 1918. (Isaphis H. & A. Adams)

Shell umbilicated; spire elevated; whorls rounded, transversely ribbed and cancellated; aperture ovate; columella slightly arcuated, with a strong tooth in the middle; outer lip simple externally, strongly lirate internally, margin dentate. (H. & A. Adams).

*Iselica fenestrata* Carpenter, 1864. (Pl. 52, fig. 11, Tryon & Pilsbry's Manual Conch., vol. 9; also pl. 13, fig. 2, Bull. U. S. Nat. Mus., No. 112). Umbilicated, spirally lirate, the lirae acute, distant, about 9 on the body whorl, the wider interstices with closer longitudinal sculpture; light yellowish brown, epidermis shaggy. Length 5-6 mm. (Tryon Manual Conch.) Puget Sound; Departure Bay, Vancouver Island, B. C.\*—Puget Sound; Departure Bay, B. C., to Gulf of California.

*Iselica obtusa laxa* Dall, 1919. Shell much resembling *I. obtusa*, but having a longer and more acute spire, much feebler spiral sculpture, and the whorls more laxly coiled, giving the suture a well-marked channel in adults. The color is grayish white, with a yellowish dehiscent periostracum and the umbilicus is a narrow chink, partly



covered by the reflected inner lip. Height of shell, 8.5; of last whorl, 6.5; diameter, 5 mm. (Dall). Maple Bay, Vancouver Island.—Vancouver Island to San Diego, Calif.

### Family ?

DIALA A. Adams, 1861

Whorls not varicose, sometimes noduled around the middle; columella straightish, not truncated; labrum not thickened. (Tryon, S. S. Conch.)

*Diala marmorea* Carpenter, 1864. (Pl. 53, fig. 87, Tryon & Pilsbry's Manual Conch., vol. 9). Shell solid, glossy, whitish, with faint chestnut longitudinal strigations; whorls flattish, suture deep; columella subtruncate. Length, 2.25 mm. (Tryon S. S. Conch.) Queen Charlotte Islands.—Queen Charlotte Islands to San Pedro, Calif.

BARLEEIA Clark, 1855

Shell conically turbinated; whorls rounded, smooth or slightly striated; aperture oval, entire, rounded in front; margins sharp. Operculum calcareous, subangular, with an internal rib-like process. (Tryon Manual Conch.)

*Barleeia sanjuanensis* Bartsch, 1919. (Pl. 13, fig. 3, Proc. U. S. Nat. Mus., vol. 58). Shell broadly conic, chestnut brown, except the nuclear whorls, which are pale brown. Nuclear turns 2, well rounded, marked by numerous rather strong pits, which are arranged in axial and spiral series. Postnuclear whorls very slightly shouldered at the summit, well rounded, marked by numerous, rather coarse incised spiral lines. Periphery obscurely angulated. Suture well marked. Base well rounded, marked like the spire. The summit of the last turn bends decidedly downward behind the aperture. Aperture sub-circular; posterior angle decidedly obtuse; outer lip rather thick; inner lip strongly curved, appressed to the base; parietal wall covered by a thick callus, which renders the peritreme complete. Height, 2.6; diameter, 1.5 mm. (Bartsch). Orcas Island, Wash.\*—Puget Sound to Point Abreojos, Lower California.

*Barleeia oldroydi* Bartsch, 1920. (Pl. 13, fig. 9, Proc. U. S. Nat. Mus., vol. 58). Shell narrowly conic, light chestnut brown. Nuclear whorls  $1\frac{3}{4}$ , well rounded, marked by slightly retractorily slanting rows of exceedingly minute pits, which appear to be arranged also in spiral series. Postnuclear whorls almost flat, appressed at the summit, marked by fine incremental lines and exceedingly fine, closely spaced

spiral striations. Sutures only slightly constricted. Periphery of the last whorl obsoletely angulated. Base moderately long, moderately well rounded. Aperture moderately large, oval; posterior angle obtuse; outer lip thin; the curved inner lip joins the basal lip in a curve; inner lip appressed to the base for a little more than half its length, the extreme anterior portion only being free; parietal wall covered by a thick callus, which renders the peritreme complete. The summit of the last turn falls slightly below the peripheral angle at the aperture; Operculum typical. Height, 3.3; diameter, 1.5 mm. (Bartsch). Vancouver Island.—Vancouver Island to Coronado Islands, Lower California.

### Family RISSOIDAE

#### ALVANIA (Leach) Risso, 1826

Shell oval, turbiniform; spire short, with sharp apex; whorls rounded, nodulously cancellated; aperture subcircular, crenulated or grooved within, outer lip marginated exteriorly by a varix. (Tryon Manual Conch.)

*Alvania carpenteri* Weinkauff, 1885. (Pl. 29, fig. 8, Proc. U. S. Nat. Mus., vol. 41). Shell small, elongate ovate, yellowish white. Nuclear whorls  $1\frac{1}{2}$ , smooth, well rounded. Post-nuclear whorls well rounded; the first 2 slightly slopingly shouldered at the summit, marked by slender, axial ribs, of which 24 occur upon the first, 32 upon the second, and 34 upon the penultimate turn. In addition to the axial ribs, the whorls are marked by spiral cords which equal the ribs in strength; of these cords, 4 occur upon the first and second turns, the space between the summit and the first cord is considerably wider than that between any of the cords and forms a sloping shoulder. On the penultimate whorl, this space is marked by 2 additional cords, one of which is at the summit and the other is halfway between this and the next cord. The spaces inclosed between the axial ribs and the spiral cords are elongated pits, which have their long axes parallel to the spiral sculpture in all cases except the median, where the pits are squarish. Suture strongly channeled. Periphery of the last whorl marked by a spiral sulcus equal to the one separating the first and second supraparipheral cords. Base moderately long, well rounded, not attenuated anteriorly, marked by 6 equal and equally spaced, spiral cords and very feeble continuations of the axial ribs, which here appear as very slender threads. Aperture broadly oval; posterior angle obtuse; outer lip thin, showing the external sculpture within; inner lip very strongly curved and slightly reflected; parietal wall

covered with a moderately strong callus, which renders the peritreme complete. Length, 2; diameter, 1.1 mm. (Bartsch). False Bay, San Juan Island and Olga, Orcas Island, Wash.\*—Forrester Island, Alaska, to Puget Sound.

*Alvania filosa* Carpenter, 1865. (Pl. 30, fig. 7, Proc. U. S. Nat. Mus., vol. 41). Shell elongate-conic, thin, translucent, yellowish white. Nuclear whorls  $1\frac{1}{2}$ , well rounded, smooth. Post-nuclear whorls well rounded, roundly shouldered at the summit, marked by slender, feebly developed, sinuous, axial riblets. In addition to these riblets, the whorls are marked by equal and equally spaced, spiral cords which are equal to the riblets in strength. Of these cords, 10 occur between the sutures on the antepenultimate, and 12 on the penultimate turn. The spaces inclosed between the spiral cords and the axial ribs are shallow, squarish pits. Suture strongly constricted. Periphery and the rather short base of the last whorl well rounded; the latter very narrowly umbilicated, marked by 8 equal and equally spaced, spiral cords, which are a little wider than the spaces that separate them. The sulci between the spiral cords on the base are crossed by the feeble extensions of the axial riblets. Aperture broadly oval; posterior angle obtuse; outer lip thin, showing the external sculpture within; inner lip moderately stout, curved and reflected, the posterior half appressed to the base; parietal wall covered with a thick callus, rendering the peritreme complete. Length, 3.5; diameter, 1.7. (Bartsch). False Bay, San Juan Island, Wash.\*—Puget Sound to Neah Bay, Wash.

*Alvania sanjuanensis* Bartsch, 1920. Shell moderately large, chestnut brown excepting the tip which is a little paler and the extreme base which is also lighter. Nuclear whorls  $1\frac{1}{2}$ , well rounded (the sculpture of the nuclear whorls eroded in all the shells seen except in a very fraction of the last turn in the type, which presents a finely, somewhat wavy, spirally lirate surface. I am not quite certain whether axial threads are present or not). Nuclear whorls strongly rounded, marked on the first turn by 3 strong spiral cords, which occupy the anterior half of the turn; on the second turn a fourth cord occurs a little anterior to the median line between the summit and the first strong cord, while on the next turn a fifth slender thread makes its appearance between the summit and this cord. This last cord at the summit never attains a strength as great as the third anterior to it, while the second one is fully as strong on the penultimate turn. In addition to these spiral cords the shell is marked by rather weak axial ribs, of which 24 occur upon the second, 26 upon the third, and about

32 upon the last turn; on this they are decidedly enfeebled. The junction of the axial ribs and spiral cords forms feeble nodules. The entire surface of the spire between ribs and interspaces is crossed by fine spiral and axial threads, which lend it a fine clothlike texture. Suture strongly constricted. Periphery of the last whorl well rounded. Base moderately long, well rounded, marked by 7 equally spaced spiral threads, of which the seventh immediately behind the inner lip is feeble. The rest are almost as wide as the spaces that separate them. The axial ribs do not extend over the base, but the fine sculpture described for the spire is also present here. Aperture ovate; posterior angle obtuse; outer lip thin at the edge, strongly curved; inner lip strongly curved, reflected and appressed to the base except at the extreme tip; parietal wall covered by a thick callus, which renders the peritreme complete. Altitude, 3; diameter, 1.5 mm. San Juan Island, Wash., by C. C. Engberg.\*—Puget Sound.

*Alvania burrardensis* Bartsch, 1921. Shell very broadly ovate, pale yellow. Nuclear whorls decollated in all our specimens. Post-nuclear whorls strongly inflated, marked by strong, rather distantly spaced curved and slightly protractively slanting axial ribs, of which 24 occur upon the next to the last and 22 upon the last turn. In addition to the axial ribs the whorls are crossed by 6 equal and equally spaced, broad spiral cords, which render the axial ribs obscurely nodulose at their junction. The spaces separating the spiral cords are a little less wide than the cords. Periphery of the last whorl marked by a sulcus, which is crossed by the continuation of the axial ribs, which extend partly over the base, but evanesces soon after passing the periphery. Base short, strongly rounded, marked by 9 equal and equally spaced prominent spiral cords, which are a little wider than the spaces that separate them. Aperture subcircular; posterior angle obtuse; outer lip reinforced by a callus at the edge; inner lip curved and appressed to the base; parietal wall covered by a moderately thick callus. Length, 2.2; diameter 2 mm. Known only from Burrard Inlet, B. C.\*

*Alvania montereyensis* Bartsch, 1911. (Pl. 30, fig. 2, Proc. U. S. Nat. Mus., vol. 41). Shell elongate-conic, yellowish-white. Nuclear whorls one and a third, well rounded, marked by about 8 very slender, spiral lirations, of which the 3 near the summit are weaker than the rest. Post-nuclear whorls well rounded, marked between the sutures by 4 strong, narrow, spiral cords, which divide the space between the sutures into 5 almost equal parts, that between the summit and the first cord being a little wider than the rest. In addition to the

spiral cords, the whorls are marked by slender axial riblets, which are about as strong as the spiral cords. Of these riblets, about 24 occur upon the first and second, and about 26 upon the penultimate, turn. The spaces inclosed between the spiral cords and the axial riblets are elongated pits, having their long axes parallel with the spiral sculpture. In addition to the above sculpture, the entire surface of the shell is marked by numerous very fine, closely spaced, spiral striations. Suture strongly constricted. Periphery of the last whorl marked by a sulcus as wide as that which separates the first suprapерipheral cord from its posterior neighbor. Base moderately long, scarcely produced anteriorly, well rounded, marked by 7 spiral cords, which grow successively weaker and closer spaced from the periphery to the umbilical region. Aperture moderately large, broadly oval; posterior angle obtuse; outer lip thin, showing the external sculpture within; inner lip slender, curved and reflected, the posterior edge touching the body whorl; parietal wall covered with a moderately thick callus, which renders the peritreme complete. Length, 2.3; diameter, 1.1 mm. (Bartsch). Olga, Orcas Island, Wash.\*—Sitka, Alaska, to Monterey, Calif.

*Alvania compacta* Carpenter, 1865. (Pl. 31, fig. 7, Proc. U. S. Nat. Mus., vol. 41). Shell ovate, light chestnut brown. Nuclear whorls  $2\frac{1}{4}$ , well rounded, smooth. Post-nuclear whorls well rounded, slightly shouldered at the summit, marked by poorly developed, slightly protractive, axial ribs, of which 24 occur upon the first and second and 30 upon the penultimate whorl. In addition to these axial ribs the whorls are marked by equal and equally spaced spiral cords, which are almost equal to the axial ribs in strength and of which 6 occur upon the first and 7 upon the second and the penultimate turn between the sutures. The first of these spiral cords is at the summit, which it renders feebly crenulate. The spaces inclosed between the axial ribs and spiral cords are rectangular pits, just a trifle longer than broad, their long axes corresponding to the spiral sculpture. In addition to the above sculpture the entire surface of the spire is marked by exceedingly fine, closely spaced spiral striations and axial lines of growth. Suture moderately impressed. Periphery of the last whorl marked by a sulcus as wide as those which separate the spiral cords on the spire. Base strongly rounded, feebly produced anteriorly, marked by 9 equal and equally spaced somewhat flattened spiral cords, which are about as wide as the spaces that separate them, and the fine sculpture noted for the spire. Aperture broadly ovate; posterior angle obtuse; outer lip thin, showing the external sculpture within;

inner lip strongly curved, slightly reflected over and appressed to the base; parietal wall covered with a thick callus. Length, 3; diameter, 1.7 mm. (Bartsch). Olga, Orcas Island, Wash.\*—Port Etches, Alaska, to Trinidad, Calif.

### Family RISSOINIDAE

RISSOINA Orbigny, 1840

Shell turreted; whorls numerous, ribbed or cancellated; aperture semilunar; lip slightly thickened within, somewhat expanded, faintly channelled anteriorly. Operculum corneous, thick, semilunar, paucispiral, with an interior process.

*Rissoina newcombei* Dall, 1897. (Plate 44, fig. 9). Shell small, elongate-conic, yellowish white. Nuclear whorls 2, well rounded, smooth. Post-nuclear whorls well rounded, appressed at the summit, marked on the first whorl by about 30 slender, protractive, axial threads which are almost as wide as the spaces that separate them. On the second whorl about 42 of the same strength occur; here also the first indication of the more prominent ribs which are characteristic of the subsequent whorls occurs. On the third whorl there are 14 slender, narrow, somewhat sinuous, protractive axial ribs which are about  $\frac{1}{4}$  as wide as the spaces that separate them. In the intercostal spaces of these whorls there are usually 3 of the finer riblets described for the whorls above. On the last whorl, the prominent riblets again become enfeebled and the surface is marked by about 36 of the finer threads. Sutures moderately impressed. Periphery of the last whorl well rounded. Base slightly concaved in the middle, marked by the continuations of the axial riblets. Aperture rather large, very oblique, slightly channelled posteriorly; outer lip claw-shaped, effuse, reinforced immediately behind the edge by a moderately thick varix; inner lip strongly curved, reflected over and appressed to the base; parietal wall covered with a moderately thick callus which renders the peristreme complete. Length, 3; diameter, 1.1 mm. (Bartsch). Cumshewa Inlet, Vancouver Island.—Forrester Island, Alaska, to Vancouver Island.

### Family SYNCERATIDAE

SYNCERA Gray, 1821. (Assimineae)

Shell conic, usually strong. Nuclear whorl smooth, the rest of the shell marked by lines of growth and fine spiral striations only. Outer lip simple; inner lip continuing over the base as a thick parietal

callus. Operculum subspiral, thin, horny. (Bartsch). Type *Assimineea hepatica* Gray. The Synceras are littoral forms, frequently inhabiting the brackish reaches of our coast.

*Syncera translucens* Carpenter, 1864. Shell broadly ovate, light brown. Nuclear whorls not differentiated from the remaining turns, well rounded. Postnuclear whorls strongly rounded, very narrowly shouldered at the summit, marked by decidedly retractively curved axial lines of growth, and exceedingly fine microscopic spiral striations. Suture strongly impressed. Periphery of the last whorl rounded. Base inflated, well rounded. Aperture subcircular; post-nuclear angle obtuse; outer lip thin; inner lip very strongly curved, thick, reflected over and appressed to the base; parietal wall covered with a thick callus which fuses with the reflected inner lip and forms a decided callosity over the umbilical region. Operculum typical. Height, 3; diameter, 1.9 mm. (Bartsch). Vancouver Island.\*—Vancouver Island to Lower California.

### Family HIPPONICIDAE

HIPPONIX Defrance, 1819

Shell thick, obliquely conical, non-spiral, apex somewhat posterior and curved backwards; muscular impression horseshoe-shaped; base of attachment shelly, secreted by the foot of the animal. (Tryon Manual Conch.)

*Hipponix antiquatus cranioides* Carpenter, 1864. (Pl. 40, fig. 6, Tryon & Pilsbry's Manual Conch., vol. 8). Shell rounded, convexly planate, the apex subcentral, radiately striate, concentrically laminate. Length, .85 of an inch. (Tryon Manual Conch.) Vancouver Island, by Rev. G. W. Taylor.—Vancouver Island to San Pedro, Calif.

### Family CREPIDULIDAE

CREPIDULA Lamarck, 1801

Shell ovate or oblong, gradually oblique, smooth exteriorly, rarely ribbed, with the apex mostly marginal and more or less beaked, interiorly hollow, with a horizontal septum-like lamina, sometimes notched at the side. (Conch. Iconica). Example *C. peruviana* Lamarck.

*Crepidula adunca* Sowerby, 1825. (Plate 11, fig. 6). Shell usually rather high, compressed on the sides, or subtriangular, with a sharp hooked beak distant from the margin, smoothish, chestnut-

brown under a light yellowish brown epidermis, with sometimes indistinct rays, more or less broken up into spots, interior also chestnut color. The original description from Tankerville Cat. App. reads: "C. testa subovali, vertice adunco, margine undata, labio interno septiformi. Obs." The internal septiform lip divides the cavity nearly in the middle—the upper being the smaller portion; this is very deep. Length 20 mm. (Tryon Manual Conch.) Reef off San Juan Island, Wash.\*—Vancouver Island to Cape San Lucas, Lower California.

*Crepidula orbiculata* Dall, 1919. Shell dextral, suborbicular, minutely concentrically wrinkled, white, covered with an olivaceous velvety periostracum; whorls about 4 counting the (lost) nucleus; the apex curved strongly to the right and elevated (in the type-specimen) about 4 millimeters above the basal margin; back evenly convex; interior subtranslucent white, the edge of the deck prominently produced at the left center with a deep sulcus at the left; there is no cavity under the spire between the deck and the margin. Height, 26; length, 20; width, 17 mm. (Dall). Royal Roads, Victoria, B. C., in 60 fathoms.—Bering Sea to San Diego, Calif.

*Crepidula aculeata* Gmelin, 1792. (Pl. 39, figs. 61-63, Tryon & Pilsbry's Manual Conch., vol. 8). Shell ovate, Haliotis-shaped, laterally incurved at the apex, radiately densely prickly-scaled. Internal appendage diaphanous-white, rather concave, slightly notched in the middle and at the side. Color white. Length 18 mm. (Conch. Iconica). Off San Juan Island, Wash., in 10-20 fathoms; rare.\*—Puget Sound to Valparaiso, Chile.

*Crepidula* (*Crepipatella*) *lingulata* Gould, 1846. (Plate 11, fig. 8). Shell small, depressed, thick at the center, but flattened and thinning toward the margin, rounded at base; the apex free, acute, slightly curving to the right; the surface near the margin furrowed with numerous, delicate, radiating lines which branch very frequently, and covered with a very delicate, pale, fugacious epidermis. Interior pale brownish-yellow, with a broadly expanded flat margin. The septum is small, white, excavated; divided by a delicate ridge, deeply detached from the left side, and at the middle projecting far and obliquely. Length  $\frac{1}{2}$ , altitude  $\frac{3}{8}$  inch. (Gould). Puget Sound.—Bering Sea to Panama.

*Crepidula* (*Ianacus*) *nivea* C. B. Adams, 1852. Shell, ovate-elliptical; rather thick; within snow white; without dingy white, sometimes with a faint tinge of brown; very irregularly concentrically more or less wrinkled, with distinct striae of growth; apex turned



more or less to the right, moderately prominent, marginal: septum longitudinally subangular, with a deep sinus at the left and a shallow one at the right: margin thick, exhibiting striae of growth. (C. B. Adams, Panama Shells). Length 44, breadth 27, height 5 mm. Off San Juan Island, Wash., in old shells, in 15-20 fathoms.\*—Puget Sound to Panama.

*Crepidula* (Ianacus) *nivea* C. B. Adams.—Color form, *a*, I. S. Oldroyd, 1922.—(Plate 11, fig. 9). This form grows on the upper and under sides of rocks, and is a much heavier shell than the typical, very much thicker and very rough. Septum white, but the rest of the shell is sometimes white, brown or purple; often spotted. Length 38, breadth 27, height 11 mm. (I. S. Oldroyd). Reef off San Juan Island, Wash.\*—Puget Sound to Lower California.

*Crepidula* (Ianacus) *nivea* C. B. Adams.—Color form *b*, I. S. Oldroyd, 1922.—(Plate 11, fig. 7). Shell smaller, heavier, thicker, septum half the length of the shell, nearly straight; at the lower edge the outline of the shell is curved, and the septum is also curved, having what seems to be growth lines following the curve. Color of the interior snow white, of the outside dirty white. Length 21, breadth 15, height 6 mm. (I. S. Oldroyd). General, in 25-35 fathoms.\*—Puget Sound to Calif.

*Crepidula* (Ianacus) *nummaria* Gould, 1846. (Plate 19, figs. 7-9). Shell thin, white, circular and perfectly flat, externally wrinkled by the loose stages of growth, and covered by a thick, yellowish epidermis. The apex is marginal and scarcely visible. The internal lamella is broader than long, arching so as to enlarge the cavity which would otherwise be almost nothing. Its edge is flexuous, retreating near the middle. Diameter,  $\frac{3}{4}$  of an inch. (Gould). Straits of Fuca.—Plover Bay, Bering Strait, to Mazatlan, Mex.

*Crepidula* (Ianacus) *nummaria fimbriata* Reeve, 1859. (Fig. 11, Reeve & Sowerby's Conch. Iconica, 1859). Shell obliquely ovate, flat, laterally incurved at the apex, concentrically striated, conspicuously laminarily frilled toward the margin, transparent-white without and within, stained with a livid-brown ray on one side; appendage notched at the side. This species is of a pure white substance, marked on one side with a single dark ray, which seen through the outer coat, has a milk appearance. Toward the margin the shell is developed in irregular fimbriated layers. "Vancouver's Straits." (Reeve).—Vancouver Island to Gulf of California.

**Family CALYPTRAEIDAE**

CALYPTRAEA Lamarck, 1799

Shell conical, more or less regular, with subcentral, subposterior sharp apex; aperture basal, with a central lamina, half cup-shaped, attached to the apex and open in front. (Tryon S. S. Conch.)

*Calyptraea fastigiata* Gould, 1846. (Plate 11, fig. 5). Shell small, thin, smooth, rounded at base, elevated-conical; the apex central, acute; the spire composed of 3 flattened whorls. Surface faintly marked by very delicate lines of growth, and covered by a thin, pale-yellow epidermis. Interior white, with a spiral lamella (septum) commencing at the vertex and making half a revolution, terminating at the margin; its free edge folded. Diameter,  $\frac{1}{2}$  an inch; height,  $\frac{5}{8}$  of an inch. (Gould). San Juan Island, Wash., and general.\*—Port Etches, Alaska, to Puget Sound.

**Family NATICIDAE**

NATICA Scopoli, 1777

Shell subglobular; spire slightly elevated; aperture half round; a spiral columella callus entering the umbilicus. (Tryon S. S. Conch.) Type *N. canrena* Lamarck.

*Natica* (Cryptonatica) *clausa* Broderip & Sowerby, 1829. (Plate 3, fig. 3). Shell with a closed umbilicus, subglobose, spire short, whorls rounded, smooth or slightly eroded, aperture semilunar, lip simple, columella rather thin, with a small broad callosity filling the umbilicus; light dull brown. Height 40 mm. Off San Juan Island, Wash., in 25-30 fathoms.\*—Arctic Ocean to Puget Sound; Atlantic; Japan.

*Natica* (Cryptonatica) *aleutica* Dall, 1919. (Plate 22, fig. 12). Shell large, rounded, slightly flattened in front of the suture, pinkish white, covered with a light brownish, spirally striated periostracum, a white area surrounding the umbilical region; whorls 6 or more, the nucleus minute; aperture lunate, simple, the body with a coat of enamel, the umbilicus completely, smoothly filled with a semulate pad of callus; operculum solidly calcareous, smooth, with an obscure swelling centrally. "This is the shell which has long been confounded with and distributed under the name of *N. russa* Gould, but the discovery of Gould's type shows that it is a much smaller and different species." (Dall). Off San Juan Island, Wash., in 25-35 fathoms.\*—Nunivak Island, Alaska, to Puget Sound and Japan.

## POLINICES Montfort, 1810

Shell oval or suboval, solid, smooth; spire short, sharp; aperture semicircular; inner lip oblique, callous, the callus extending into the umbilicus. Operculum corneous. (Tryon S. S. Conch.)

*Polinices* (Euspira) *pallida* Broderip & Sowerby. (Plate 3, fig. 2). Shell ovately globose, narrowly umbilicated, smooth, dirty white under a yellowish brown thin epidermis. Length 28 mm. (Tryon Manual Conch.) Off San Juan Islands, Wash., in 25 fathoms.\*—Arctic Ocean to Puget Sound; Okhotsk Sea.

*Polinices* (Euspira) *algida* Gould, 1848. (Fig. 256, Gould's Mollusca and shells of the U. S. Explor. Exped., 152;—under Wilkes). Shell small, rather thin, globular, smooth, of a pale bluish-white color. Whorls 4, forming a rounded, slightly elevated spire, the last one very capacious, with a narrow shoulder near the suture. Aperture semilunar, outer lip thin; inner margin curved, covered posteriorly by callus, which is not very closely appressed. There is a rather large, open, somewhat spiral umbilical opening, externally margined by an angle, and partially filled by a revolving pillar, on which is an expansion of the callus. Axial diameter  $\frac{5}{8}$  of an inch; transverse diameter  $\frac{3}{5}$  of an inch. (Gould). Puget Sound.—Coal Harbor, Shumagin Islands, Alaska, to Puget Sound.

*Polinices* (Euspira) *caurina* Gould, 1847. (Fig. 254, Gould's Mollusca and shells of the U. S. Explor. Exped., 1852;—under Wilkes). Shell small, solid, smooth, of a round-ellipsoid form, of a dead, dirty milk-white color; whorls 4 or 5, the upper ones forming a depressed spire, with the apex eroded, and the suture linear; the last whorl very large, full posteriorly, and somewhat tabular at the suture; the last whorl is quite as long as broad, and perhaps attenuated at base. The aperture is about two-thirds the length of shell, simular; the outer lip sharp, the pillar lip straight, heavily and broadly loaded with callus posteriorly, and regularly narrowing, and yet nearly covering a small umbilical pit at the middle, so as to leave merely a small, linear chink, or none at all. Axial diameter  $\frac{1}{2}$  an inch; transverse diameter 2-5 of an inch. (Gould). Puget Sound.—Norton Sound, Alaska, to San Diego, Calif.; in deep water.

*Polinices* (Euspira) *lewisii* Gould, 1847. (Plate 36, fig. 1). Shell very large, not very ponderous, globose-conic; the spire rather elevated and acute; color pale fleshy, covered by a thin, ashy epidermis, which is everywhere marked with very delicate, crowded, undulating, revolving lines. Surface somewhat undulated by the stages of growth.

Whorls 6, moderately convex, somewhat flattened near the suture, the last whorl having a very remarkable broad, well-marked constriction, at about its posterior third, which is continued also about the middle of the posterior whorls. Aperture ovate, broad, having a sharp lip, until it rises on the left margin, when it widens, and presents a rounded edge, terminating in a copious white callus, which seems to flow down about half way around the umbilicus without closing it, and having a furrow running obliquely inward, from the upper edge of the umbilicus; its edges are somewhat tinted with chestnut, and a strong band of callus also fills the upper angle of the aperture. Umbilicus moderately long, deep, nearly round, with a slight encroachment down the right wall. Interior of the aperture shaded with pale flesh-color. Operculum thin, horny. Axial diameter  $4\frac{1}{2}$  to 5 inches; transverse diameter 4 inches. (Gould). Olga, Orcas Island, Wash.\*—Duncan Bay, B. C., to Magdalena Bay, Lower California.

*Polinices draconis* Dall, 1903. (Plate 36, figs. 2a, 2b). Shell depressed, solid, cream color, sometimes with a ferruginous or livid tinge, with 6 whorls; nuclear whorls very small, smooth; later ones with an obscure, nearly obsolete spiral sculpture like flattened-out thread over which run microscopic, close-set, spiral striae; suture with the whorl in front of it feebly channelled and the excavation bounded by an obsolete thread; top of the whorls flattened, part of the base bordering the umbilicus also flattish, the remainder of the whorl rounded, turgid; umbilicus wide and deep, its walls excavated and closely spirally striated, aperture oblique, semi-lunate, outer lip thin, base rounded; the angle where the lip meets the body, filled with a smooth white callus, the anterior angle of the pillar lip also thickened. Height of shell, 51; of last whorls, 49; of aperture, 44; max. width of shell, 50 mm. (Dall). Friday Harbor, Wash., by C. C. Engberg.—Port Althorp, Alaska, to Catalina Island, Calif.

This species has no close resemblance to any of the other species of the region. The pillar lip is somewhat thickened with a small purplish brown callus in the perfect shell. The sculpture and the depressed form seem characteristic. From *P. lewisi* Gould, it is easily separated by its smaller size, depressed form and wide umbilicus pervious almost to the apex of the shell. (Dall).

*Polinices* (*Euspira*) *groenlandica* (Beck) Moller, 1842. (Pl. 21, fig. 15, G. O. Sars' Mollusca Reg. Arct. Norv.) Shell scarcely umbilicated, globose, spire rather large, exserted, whorls rounded, smooth, aperture lunar-ovate, columella callously reflected at the lower part, opaque-white, covered with a greenish-ash epidermis, more or less

eroded toward the apex. Height 23, diameter 15 mm. (Reeve Conch.) Seattle, Wash., by G. D. Hanna.\*—Arctic Ocean to Monterey, Calif.; Greenland.

### Family LAMELLARIIDAE

#### LAMELLARIA Montagu, 1815

Shell internal, ear-shaped, thin pellucid; spire lateral, very small; aperture large, patulous, both lips regularly arcuated; axis imperforate. No operculum. (Tryon Manual Conch.)

*Lamellaria stearnsii* Dall, 1871. (Pl. 15, fig. 6, Amer. Journ. Conch., vol. 7, pt. 2). Shell pure white, suborbicular, depressed, of 3 whorls. Columella sharp, thin, widely arcuated; loosely twisted so that the apex is discernible from below. Spire hardly elevated above the last whorl; suture distinct, sharply defined; aperture very effuse, rounded. Exterior marked by lines of growth, crossed by microscopic fine revolving striulae. Interior polished. Lat. .26, lon. .2, alt. 1.2. inches. (Dall). Off entrance of East Sound, Wash., in 25 fathoms.\*—Puget Sound to San Diego, Calif.

*Lamellaria rhombica* Dall, 1871. (Pl. 15, figs. 4, 5, Amer. Journ. Conch., vol. 7, pt. 2). Shell pure white, subrhombical in shape, moderately elevated, of three whorls. Columella thickened, stout, reflected, narrow, with a groove behind the callus, whorls appressed against, and slightly flattened below, the suture; spire very small, not elevated; apex not above the level of the last whorl. Aperture subquadrate, outer lip very much produced, slightly angulated above and below. Suture deep appressed. Nucleus smaller than in *L. stearnsii*; surface of the whorls smooth, without striulae. Lat. .46, lon. .32, alt. .2 inches. (Dall). Off San Juan Island, Wash., in 25 fathoms.\*—Puget Sound to Magdalena Bay, Lower California.

### Family VELUTINIDAE

#### VELUTINA Fleming, 1822

Shell thin, mostly external, calcareous, uniform, paucispiral, invested by a velvety epidermis; spire lateral, suture well impressed; aperture large, rounded, the lip thin, the columellar lip a little reflected. No operculum. (Tryon Manual Conch.)

*Velutina prolongata* Carpenter, 1865. Pink under a smooth, thin, yellowish epidermis, the growth-lines crossed by very fine slightly spiral impressed striae; whorls  $3\frac{1}{2}$ , the last very large, suture deeply impressed; aperture long oval, junction of columellar and outer lip some-

what angulated. Length 10 mm. (Tryon Manual Conch.) Off San Juan Island, Wash., in 25 fathoms.\*—Bering Strait to Monterey, Calif.

*Velutina laevigata* (Linne) Mueller, 1776. (Plate 5, fig. 10). Shell thin, translucent, whitish, or usually light pink, with numerous fine revolving striae crossing the minute growth lines; epidermis thin, transparent horn-color, somewhat tufted on the revolving striae; whorls  $3\frac{1}{2}$ , suture deeply impressed. Length 16 mm. Off San Juan Island, Wash., in 25 fathoms.\*—Icy Cape, Arctic Ocean to Monterey, Calif.; Atlantic.

### Family LEPETIDAE

LEPETA Gray, 1847

Shell patelliform, the embryonic nucleus spiral, lost in the adult; apex in front of the middle; no internal septum. (Tryon Manual Conch.) Type *L. caeca* Muller.

*Lepeta* (Cryptoctenidia) *concentrica* Middendorff, 1851. (Pl. 16, fig. 6, Middendorff's Sibirische Reise; also pl. 15, fig. 2, Amer. Journ. Conch., vol. 5, pt. 3). Shell depressed conical, apex directed forward; front slope one-third of the length of the shell or a little less; surface faintly radiately striate (more distinctly so in young specimens), not decussated or granulose; light-brownish or greenish tinted. The outline is ovate, a little narrower in front; front slope slightly concave, posterior slope convex. The fine thread-like radiating striae are larger on the longer slope of the shell; they are not interrupted by concentric growth-lines, the latter being inconspicuous, or sometimes strongly impressed at intervals. Epidermis very thin, yellowish-brown, deciduous. Inside polished, white, the anterior terminations of the muscle-scar a little behind the apex. Edges of shell level, narrowly bordered with gray, especially in the young. Length 20.5, breadth 16, alt. 6 mm. (Tryon Manual Conch.) Off San Juan Island, Wash., in 25 fathoms.\*—Icy Cape, Arctic Ocean, to Puget Sound; Okhotsk Sea.

### Family ACMAEIDAE

ACMAEA Eschscholtz, 1830

Shell patelliform, conical, the apex more or less anterior, the embryonic shell conical, not spiral. (Tryon Manual Conch.)

*Acmaea mitra* Eschscholtz, 1833. (Pl. 23, fig. 4, Eschscholtz's Zool. Atlas; also pl. 15, figs. 5 a-c, Amer. Journ. Conch, vol. 5). Shell dull-white, aperture nearly circular, wider behind, in some young

examples somewhat elongated, oval; form conical, apex erect, nearly central, blunt, smooth, posterior surface usually straight, but occasionally a little convex; exterior smooth marked with very faint concentric lines of growth, devoid of epidermis; margin entire, polished, with a narrow semi-pellucid rim inside. Internally smooth or furnished with grooves radiating from the apex more or less strongly marked. Muscular impressions deep, strong, horseshoe-shaped, with the marks of the anterior ends of the adductors rounded and broader than the rest, connected by a slender impressed line marking the attachment of the mantle. Young shells are often furnished with irregular riblets more or less strong, many or few in number, radiating from the apex, but stronger towards the margin. Color dead-white inside and out, often livid or tinged a fine pink or pea-green from Nullipore, never wax-yellow or horny-pellucid as in the normal state of *Scurra scurra*. Length, 35; breadth, 31; height, 23 mm. (Tryon Manual Conch.) General on all the San Juan group of islands, Wash.\*—Bering Sea to San Diego, Calif.

*Acmaea cassis* Eschscholtz, 1833. (Plate 21, figs. 5, 6). Shell solid, having stout radiating ribs about 25-27 in number, those in front narrower or obsolete. Dark spot of the inside small or obscured; margin with a mere dark line, or a series of scollops between the ribs. Outside dull, grayish. Length, about, 28 mm. (Tryon Manual Conch.) Victoria, B. C.—Aleutian Islands to San Francisco, Calif.

*Acmaea cassis pelta* Eschscholtz, 1833. (Pl. 8, figs. 90, 91, Tryon & Pilsbry's Manual Conch., vol. 13). Shell oval, conical, apex a little in front of the middle. Surface having rather coarse low ribs. Dark border of the inside very narrow, or reduced to a series of dark scollops. Length 40-45 mm. (Tryon Manual Conch.) San Juan Island, Wash., and general.\*—Okhotsk Sea to Rosario Bay, Lower California, and Socorro Island, Mex.

Tryon says that the prominent characters of the variety are the erect, conical form, rather wide, coarse ribs, and the narrow margin of the inside, usually not continuous but composed of scollops or square spots. In the typical form of this variety the central dark spot of the interior is rather small or wanting.

*Acmaea cassis olympica* Dall, 1914. (Plate 21, figs. 12, 13). Shell small, conical, elevated, having much the shape of *A. mitra*. The color outside is gray, pink or light purple; painted with a few or many black stripes. A dark spot is inside. Ribs obsolete. Length 25-30 mm. (Tryon Manual Conch.) Nanaimo, Vancouver Island.\*—Alaskan Peninsula to San Diego, Calif.

*Acmaea cassis nacelloides* Dall, 1871. (Plate 21, figs. 7-9). Shell of a blackish brown, with sharp, radiating grooves sometimes obsolete near the apex. Several shells beginning in this way have a margin with the normal characters of *A. pelta*. Length 20-25 mm. (Dall). Gull Rock, San Juan County, Wash.; one specimen.\*—Attu Island, Alaska, to San Diego, Calif.

*Acmaea scutum* Eschscholtz, 1833. (Plate 21, figs. 3, 4). Testa ovato-oblonga convexa transversim striata, exus olivacea, lineis flavescenscentibus radiantibus inaequalibus picta; intus livida, macula subornice fusca spathulaeformi magna, vertice subcentrali obtusissimo, margine crenato. (Eschscholtz). Although he uses crenate for the margin he refers to the color spots, not to actual crenations, and figures an entire margin. (Dall). This is the shell we have always called *A. patina*. Length about 60; breadth about 50; height about 13 mm. General on all the San Juan group of islands.\*—Okhotsk Sea to Gulf of California.

*Acmaea scutum patina* Eschscholtz, 1833. (Pl. 24, figs. 7, 8, Eschscholtz's Zool. Atlas, pt. 5). Shell large, oval or rounded-oval, depressed-conic, the apex rounded and near the middle; slopes slightly convex. Surface obsoletely radiately striated, olive-gray, tessellated, or more rarely striped, with black. Inside white with an irregular brown central area and a rather wide dark or tessellated border. Length, 53; breadth, 46; height, 18 mm. (Tryon Manual Conch.) San Juan Island, Wash., general.\*—Okhotsk Sea to Gulf of California.

*Acmaea scutum pintadina* Gould, 1846. (Plate 21, fig. 14). Shell large, flat, open. Apex subcentral. Color tessellated with white and ashy-brown olive, in various proportions. Inside, the shell is generally of porcellaneous white, with a squarely tessellated border, in which sometimes the light, sometimes the dark predominates. (Carpenter). Length 25-45 mm. Sucia Island, Wash.\*—Aleutian Islands to Monterey, Calif.

*Acmaea scutum cribraria* Carpenter, 1866. *A. scutum* is internally almost always dark in the spectrum, with white sides. But sometimes there are concentric zones of dark, alternating with the white, in which state it is the *cribraria* Gld. ms. (Carpenter). Neah Bay, Wash.—Neah Bay, Wash., to Santa Barbara, Calif.

*Acmaea digitalis* Eschscholtz, 1833. (Plate 21, figs. 10, 11). This is the most usual form found north of San Francisco Bay. It is dull, lustreless, whitish, with stripes and zigzags of blackish-brown. The apex is usually decidedly anterior and elevated; the front ribs are obsolete, the posterior ribs strong, rounded, often uneven. Inside



margin conspicuously tessellated; central area generally dark and rather narrow. Length, 25-30 mm. (Tryon Manual Conch.) Gull Rock, San Juan County, Wash.\*—Aleutian Islands to Monterey, Calif.

*Acmaea rosacea* Carpenter, 1866. (Pl. 7, fig. 71-73, Tryon & Pilsbry's Manual Conch., vol. 13). Shell small, conical, thin, smooth or with very obsolete ribs. The young are pale roseate, with a few white and brown subradiating spots; the adults have rosy brown and whitish streaks or are dotted with pale rose. Apex elevated, a little anterior; inside white or rosy. Length, 8; breadth, 6.25; height, 3.5 mm. (Tryon Manual Conch.) Departure Bay, Vancouver Island, by Rev. G. W. Taylor.—Gulf of Georgia to Acapulco, Mex.

*Acmaea instabilis* Gould, 1846. (Plate 21, figs. 1, 2). Shell narrow and oblong, the basal margin elevated at the ends; texture thin; slopes convex or bulging. Surface finely radiately striated; dark brown or black. Inside white or bluish, with or without a faint brown spot in the cavity. (Tryon Manual Conch.) Lives on the stalks of the large kelp. Length 38, breadth 23, height 11-15 mm. Vancouver Island to San Pedro, Calif.

*Acmaea asmi* Middendorff, 1849. (Plate 21, figs. 15, 16). Shell small, thin but strong and solid, elevated, conical, the base short-oval, apex erect, a little in front of the middle; slopes of the cone somewhat convex. Surface lusterless, usually corroded, smooth except for very fine radiating striae visible with the aid of a lens, but obsolete in adult shells. Color rusty black. Inside black, with a brown zone just outside the muscle-scar. Length, 10; breadth, 8.5; height, 7 mm. (Tryon Manual Conch.) Puget Sound? Sitka, Alaska, to Turtle Bay, Lower California; Socorro Island, Mex.

### Family PHASIANELLIDAE

#### PHASIANELLA Lamarck, 1804

Shell elongated, polished, richly colored; whorls convex; aperture oval, not pearly; inner lip callous, outer thin; operculum shelly, callous outside, subspiral inside. (Tryon S. S. Conch.)

*Phasianella* (*Eulithidium*) *lurida* Dall, 1897. (Plate 44, fig. 11). Shell small, solid, turbate, of 4 whorls, of a lurid purple color, slightly paler on the base and apex; whorls rounded, sculptured only by feeble lines of growth, polished; suture distinct; base rounded with feeble spiral striations; aperture rounded; peritreme sharp edged, smooth within, the lips united over the body by a wash of callus;

umbilical region imperforate. Most of the specimens are marked with whitish dots, which I believe to be due to sessile Polyzoa, which are apt to leave such marks when removed. Height 3.75, diameter 3 mm. (Dall). Vancouver Island.—Vancouver Island to Mendocino County. Calif.

### Family TURBINIDAE

#### ASTRAEA Bolten, 1798

Shell not umbilicated; spire more elevated. Operculum externally subspiral, and with a central pit. (Tryon S. S. Conch.)

*Astrea* (Pachypoma) *inaequalis* Martyn, 1784. (Pl. 31, Martyn's Figs. Nondescript Shells). Shell conic, imperforate, rather solid, with a chestnut brown cuticle, lighter beneath; whorls 6-7, planulate above, sutures slightly impressed, bordered below by a series of obliquely descending corrugations, which are cut into granules by from 1 to 5 spiral furrows; periphery carinate, subspinose on the upper whorls, usually nearly smooth on the body-whorl; base nearly flat, concentrically lirate, the lirae more or less tuberculate, 5 or 6 in number, their interstices regularly striate; aperture subtriangular, white within, the lower margin fluted; columella arcuate, broad, excavated at position of the umbilicus, and terminating in a tooth-like prominence below. Alt. 45, diam. 55-62 mm. (Tryon Manual Conch.) Vancouver Island.—Vancouver Island to San Pedro. Calif.

#### LEPTOTHYRA (Carpenter) Pease, 1869

Shell small or minute, globose-depressed, solid, compact; umbilicate or imperforate, whorls 3-7, spirally sculptured, the last generally somewhat deflected at the aperture; aperture subcircular, white and nacreous within; columella generally but not always bluntly denticulate near the base. Operculum subcircular, nearly flat or concavo-convex, inside with a very thin corneous layer, slightly convex, with many gradually increasing whorls, the nucleus subcentral; outside calcareous, subspiral, with a slightly convex concentric elevation or ridge around the margin, most prominent at its termination, the middle portion concave and more or less rugose. (Tryon Manual Conch.)

*Leptothyra carpenteri* Pilsbry, 1888. (Pl. 39a, fig. 26; and pl. 60, fig. 66, Tryon & Pilsbry's Manual Conch., vol. 10). Shell small, globose, very solid, imperforate, spire conic, more or less depressed; suture moderately impressed; whorls 5, slightly convex, the last decidedly deflected toward the aperture, encircled by about 15 subequal

spiral lirae, separated by interstices about as wide as the ridges; incremental striae generally strongly developed, causing the lirae to appear nodose or somewhat irregular, and the interstices to appear pitted; aperture oblique, pearly white within, about half the length of shell; columella arcuate, base obsoletely 1-3-dentate; color red, ashen or purple. Height, 8; diameter, 8.9 mm. (Tryon Manual Conch.) San Juan and Orcas Islands, Wash.\*—Sitka Sound, Alaska, to San Diego, Calif.

*Leptothyra lurida* Dall, 1885. (? Pl. 39a, fig. 27-29, Tryon & Pilsbry's Manual Conch., vol. 10). This form has a dull olivaceous cast sometimes mottled with whitish. The sculpture is more compact and closer, the nacre less brilliant than that of Monterey specimens; they are also smaller on the average. (Dall). San Juan and Orcas Islands, Wash.\*—Puget Sound to Cape San Lucas, Lower California.

*Leptothyra bacula* Carpenter, 1864. (Pl. 39a, fig. 33, Tryon & Pilsbry's Manual Conch., vol. 10). Shell small, depressed-globose, solid, imperforate, rufous ashy; whorls 4 slightly convex, rapidly increasing, obsoletely but regularly spirally striate; aperture large, oblique, deflexed above. Alt., 4; diameter, 5 mm. (Tryon, Manual Conch.) Brown and Orcas Islands, Wash.\*—Vancouver Island to Lower California.

### Family LIOTIDAE

MOLLERIA Jeffreys, 1865

Shell remarkably solid, with strong and partly dichotomous transverse ribs; peristome continuous. Operculum calcareous, multispiral. (Tryon S. S. Conch.)

*Molleria quadrae* Dall, 1897. (Pl. 44, figs. 7, 8). Shell small, solid, straw-colored or brownish, with 3 rapidly enlarging well rounded whorls; spire depressed, suture very distinct, umbilicus narrow and deep; surface microscopically spirally striate, the sculpture coarser on the base, but visible with a lens on the upper surface also; aperture circular, peritreme continuous, simple; operculum multispiral, calcareous, centrally slightly concave on the outer side. Diameter, 1.8; alt. 1 mm. (Dall). Cumshewa Inlet, Queen Charlotte Islands, B. C. —Amchitka Island of the Aleutian Islands to Queen Charlotte Islands.

### Family TROCHIDAE

HALISTYLUS Dall, 1889

Shell small, cylindrical, holostomate, polychromatic; operculum multispiral, coriaceous. (Dall). Type *H. columna* Dall.

*Halistylus subpupoides* Tryon, 1887. (Pl. 60, fig. 77, Tryon & Pilsbry's Manual Conch., vol. 9). Whorls about 6, convex, closely spirally striate, thin, light, olivaceous or brownish, with a series of chestnut spots under the suture; lip simple. Length 6 mm. (Tryon Manual Conch.) Victoria, B. C., by Dr. C. F. Newcombe.—Queen Charlotte Islands to Panama.

TEGULA Lesson, 1832

Shell conical, spire pointed, with revolving granulated ribs; columella spirally twisted, terminating anteriorly in a large obtuse tubercle. (Tryon S. S. Conch.)

*Tegula* (*Chlorostoma*) *funeralis* A. Adams, 1854. (Pl. 28, figs. 42-44, Tryon & Pilsbry's Manual Conch., vol. 11). This species is similar to *T. gallina* in form and characters of the aperture. It is lusterless, purple or black, the apex usually eroded, orange-colored; the teeth of the columella are white; and there is never a yellowish streak at the base, as in *T. gallina* var. *tincta*. The whorls are spirally lirate, sometimes smooth except on the base, sometimes strongly lirate above. The suture is margined below by an impressed line, and by elevated, foliaceous incremental lamellae. This last feature may almost always be detected, although sometimes but very slightly developed. Alt. 35; diam. 32 mm. (Tryon Manual Conch.) Vancouver Island.\*—Vancouver Island to Cerros Island, Lower California.

*Tegula* (*Chlorostoma*) *funeralis subaperta* Carpenter, 1864. Shell with umbilical pit. (Carpenter). Neah Bay, Wash.—Neah Bay, Wash., to San Pedro, Calif.

*Tegula* (*Promartynia*) *pulligo* Martyn, 1784. (Plate 20, figs. 3, 4). Shell deeply and widely umbilicate, conical, solid, dull purplish or brown, when worn often orange, obliquely streaked with white or unicolored; spire elevated; whorls 7, flattened, the upper ones finely spirally striate and sometimes very obsoletely plicate; the remainder smooth, obliquely finely striate; base flattened, slightly convex, obliquely streaked, concave and white around the umbilicus; body-whorl bluntly angled at the periphery; aperture very oblique, smaller than usual in the subgenus *Chlorostoma*; columella thin, obtusely dentate, ending above in a white callus which partly covers the umbilicus. Alt. 35; diameter, 32 mm. (Tryon Manual Conch.) Vancouver Island, by Rev. G. W. Taylor.\*—Sitka, Alaska, to Calif.

*Tegula pulligo taylora* new subspecies, 1922. (Plate 20, fig. 1, 2).

Shell very like the typical form, but the periphery is rounded instead of angular; the umbilicus larger; blunt dentition on the inner lip as in the typical form; color of shell reddish, and the white patch around the umbilicus larger, with the umbilical area very much deeper; the base convex and the edge of the outer lip thin and red, with a dull strip between that and the pearly interior. Shell nearly twice the size of the typical, and more elevated. The type and 3 specimens in the Taylor collection. Height of type, 40; of the base, 36 mm. Known only from Hope Island at the north end of Vancouver Island; collected by Rev. G. W. Taylor.\*

CALLIOSTOMA, Swainson, 1840

Shell trochiform, conical, not umbilicated; last whorl angulated and usually ribbed at the periphery; aperture quadrangular; columella simple, oblique, often ending in a tooth in front. (Arnold).

*Calliostoma annulatum* Martyn, 1784. (Pl. 33, Martyn's Figs. Nondescript Shells; also pl. 67, fig. 43, Tryon & Pilsbry's Manual Conch., vol. 11). Shell elevated-conic, imperforate, rather thin; light yellow, dotted with brown on the spiral rows of grains, the periphery or lower edge of each whorl encircled by a zone of violet or magenta, the axis surrounded by a tract of the same. Surface with numerous granose lirae, about 7 on the penultimate whorl, 9 or 10 on the base. Spire conical, apex acute, minute, reddish; sutures slightly impressed. Whorls about 9, slightly convex, the last angular at the periphery, flattened beneath; aperture rhomboidal, oblique, fluted within. Height, 30; diameter, 25 mm. (Tryon Manual Conch.) Off San Juan Island, Wash., general 25-30 fathoms.\*—Alaska to San Diego, Calif.

*Calliostoma variegatum* Carpenter, 1865. (Pl. 39, fig. 10, Proc. U. S. Nat. Mus., vol. 24). Shell small, conical, variegated; nucleus rosaceous; whorls 6, planate; sutures hardly impressed; spire with 3 regular, nodulous riblets, the nodules whitish, subdistant; interspaces very elegantly rosy; lirulae of the base 8, scarcely nodulous, spotted with rosy. Height, 31; diameter, 25 mm. (Tryon Manual Conch.) Off San Juan Island, Wash., general in 25-30 fathoms.\*—Puget Sound to Cerros Island, Lower California.

*Calliostoma costatum* Martyn, 1784. (Pl. 34, Martyn's Figs. Nondescript Shells; also pl. 16, figs. 6, 9, Tryon & Pilsbry's Manual

Conch., vol. 11). Shell conical, rounded at the periphery, base flattened; imperforate; solid; dark chestnut colored, the spiral riblets lighter; apex dark, usually purple. Surface encircled by numerous spiral smooth riblets, their interstices closely finely obliquely striate; riblets usually 7-9 on the penultimate whorl, about 9 on the base. Spire conic; apex acute; suture impressed. Whorls about 7, convex, the last rounded (or a trifle angled) around the lower part, slightly convex beneath; aperture rounded, oblique, outer lip fluted within, with a beveled opaque white submargin; throat pearly, iridescent; columella simple, arcuate. Height, 20; diameter, 18 mm. (Tryon Manual Conch.) Off San Juan Island, Wash., in 20 fathoms and general on shore.\*—Alaska to San Diego, Calif.

*Calliostoma costatum caeruleum* Dall, 1919. Shell resembling the ordinary typical form except that the apex and part of the whorls in front of the suture are colored with bands of a brilliant mazarin blue when fresh, but which unfortunately fades after a few years in the cabinet. Fresh specimens have a very different aspect from the common shells carrying reddish spiral lines on a yellowish ground. (Dall). Neah Bay, Wash.—Neah Bay, Wash., to Monterey, Calif.

*Calliostoma costatum pictum* Dall, 1919. These shells resemble the type except that on the periphery of the whorl, and sometimes on the whorl between the periphery and the preceding suture, the shell is adorned with alternating light and dark patches or clouds of color. (Dall). Neah Bay, Wash.—Neah Bay, Wash., to Monterey, Calif.

#### CIDARINA Dall, 1902

Shell large, whitish, unicolor, with strong spiral sculpture sharply nodose, the umbilicus closed by a reflected layer of callus, the suture channeled. Deep waters of the west coast of North America. (Dall).

*Cidarina cidaris* A. Adams, 1864. (Plate 5, fig. 16). Shell conical; spire elevated, subarcuate; whorls 6-7; 4 upper whorls only slightly convex; lower whorls very convex; surface ornamented with spiral rows of nodes which grade into nodose ribs on the lower side of the body whorl; suture deeply impressed; aperture circular; outer lip thin; inner lip and columella enameled, the incrustation completely obscuring the small umbilicus in most specimens. (Arnold). Height 26, diameter 19 mm. Off Lopez Island, Wash.; North of Gabriola Island and at Departure Bay, B. C.\*—Kasaan Bay, Alaska, to Cape San Quentin, Lower California.

*Cidarina carlotta* Dall, 1902. (Pl. 18, fig. 4, Bull. U. S. Nat. Mus., No. 112). Shell rather depressed, pearly white covered with a dense, rather fibrous, olive-gray periostracum; nuclear whorls eroded, but the shell exhibits about  $4\frac{1}{2}$  whorls; sculpture of, on the base 8 minutely distant nodulous spiral threads stronger and more distant as one proceeds from the verge of the umbilicus to the periphery; peripheral spiral separated from another above it by an excavated channel; these 2 are the strongest on the shell, and between the upper one and the suture is another much feebler thread; the upper 2 are all that show on the spire, as the outer lip runs just above the peripheral thread; the radial sculpture comprises incremental lines, and on the last whorl about 20 low narrow somewhat oblique riblets about a millimeter apart, extending from the suture to the first peripheral keel, but not beyond; these riblets nodulate the weak spiral, but are only about half as numerous as the nodules on the peripheral spirals; suture distinct, not channeled; base rounded; the umbilicus funicular, of moderate size, bounded by an inconspicuous keel, above which the walls are vertically striated; margins of the aperture simple, sharp, the upper lip advancing where it joins the body; pillar lip thin, slightly excavated, the distal angle not prominent. Alt. 9; diam. 17.5 mm. (Dall).—Known only from the Queen Charlotte Islands.

SOLARIELLA S. Wood, 1842

Shell thin, globular-conical; generally with wide crenated umbilicus; whorls rounded, sculptured; aperture rounded; lip sharp, smooth. (Arnold). Type *S. maculata* S. Wood.

*Solariella peramabilis* Carpenter, 1864. (Plate 5, fig. 13). Shell very thin, very elegantly sculptured, livid, spotted with pale rufous-brown; nuclear whorls 2, very tumid, smooth, apex mammillated, following whorls 4, tabulated, sutures nearly rectangular; upon the spire there are 2 or 3 carinae, and intercalated carinulae; the entire surface is most elegantly and densely radiately costate, costae very acute, subgranulose upon the carinae, interstices on the first whorl fenestrated, posteriorly decussated; base deeply rounded; sculpture with about 5 lirulae, anteriorly granulose; umbilicus large, closely ornamented with about 3 spiral distant lines, and radiating costulations continued from the base. Aperture rounded, indented by the carinae, scarcely in contact parietally, iridescent inside, nacreous; operculum very thin, multispiral, with about 10 elegant radiately rugose whorls. Height, 15; diameter, 8 mm. (Tryon Manual Conch.) Off Lopez Island, Wash.; Departure Bay, B. C.\*—Forrester Island, Alaska, to Coronado Islands, Lower California; Japan.

*Solariella* (*Machaeroplax*) *varicosa* Mighels & Adams, 1842. (Pl. 4, fig. 14, Boston Journ. Nat. Hist., vol. 4). Shell small, thin, low, conical, of a dingy white or drab color; whorls 4, convex, covered with numerous longitudinal, oblique ribs; intersected by a great number of revolving striae, which are most conspicuous on the lower part and base of the lower whorl. The striae on the upper part of the whorls can only be seen with a magnifier. Suture distinct, subcanaliculate; umbilicus rather large and deep, bounded by 2 rather rugged varices, intersected by the ribs which are continued to the verge of the umbilicus. Aperture circular; labrum simple, sharp; within pearly. (Tryon Manual Conch.) Height 6.5, diameter 6.5 mm. Departure Bay, B. C.\*—Arctic Ocean to San Diego, Calif.; Atlantic.

*Solariella* (*Machaeroplax*) *obscura* Couthouy, 1838. (Pl. 3, fig. 2, Boston Journ. Nat. Hist., vol. 2; also pl. 18, figs. 11, 12, Bull. U. S. Nat. Mus., No. 112). Shell subconical, thin, color obscure reddish brown; whorls 5 in number, convex, transversed by numerous, very fine, minute, revolving striae, intersected by almost imperceptible longitudinal ones; a single slightly elevated line or rib revolves a short distance below the sutures, which are tolerably well defined; base convex, concentric basal striae scarcely perceptible; transverse striae very apparent; umbilicus moderately wide and extending nearly to the apex; aperture circular, lip sharp, smooth internally, and slightly reflected upon the umbilicus. Interior iridescent; operculum thin, horny, concentrically spiral. Height 5, diameter 5 mm. (Couthouy). False Bay, San Juan Island, Wash.; Departure Bay, B. C.\*—Arctic Ocean to Puget Sound; circumboreal.

MARGARITES Leach, 1847. (*Margarita*)

Shell umbilicate, orbicular, conoidal or depressed, thin; not variegated; whorls rounded, smooth or spirally lirate; aperture subcircular, peristome simple, acute, the margins approaching; columella arcuate, simple, thin. (Tryon Manual Conch.) Type *M. helycinus* Phipps.

*Margarites* (*Pupillaria*) *pupillus* Gould, 1849. (Plate 46, fig. 4). Shell narrowly umbilicated, conical, solid, lusterless, ashen or whitish; surface spirally traversed by unequal cord-like lirae, separated by sharply crispate-striate interspaces, as wide or wider than the ridges. The latter are nearly smooth or showing traces of the oblique striation; upon the last  $1\frac{1}{2}$  whorls there is usually a spiral thread in the interlirar spaces; above this there are 4 or 5 lirae on each whorl. Upon the base the concentric riblets decrease regularly in size from the



center outward, and number about 12. The spire is elevated; apex subarcuate; sutures impressed; whorls 6, convex, the last obtusely angled, flattened beneath; aperture very oblique, rounded, iridescent inside; periostome simple, columella arcuate, subreflexed at the umbilicus, often nearly closing it, united with the upper termination of the lip by a parietal callus; umbilicus bounded by a carina, funnel-shaped, its perforation very small. Height, 13; diameter, 12 mm. (Tryon Manual Conch.) General on shore and dredged in 15-30 fathoms.\*—Bering Sea to Monterey, Calif.

*Margarites* (Lirularia) *succinctus* Carpenter, 1864. (Plate 45, fig. 11). With small shell, subelevate, rather solid, pale; young shell with narrow furrows, very numerous, lined with dark purple; adult shell nebulous with spots equally large; whorls 5, subquadrate; girdled with obtuse median lirae, and subobsolete striae, with suture strongly impressed, with rounded base obtusely angulated, ornamented with striae often becoming obsolete; with the adult shell often rather tumid impressed in the middle around the large funnel shaped scarcely angulated umbilicus. Aperture subquadrate, slightly dependent. Columella subarcuate. (Free translation from Carpenter). Length 16, height 16 mm. Olga, Orcas Island, Wash.\*—Sitka, Alaska, to San Diego, Calif.

*Margarites* (Lirularia) *funiculatus* Carpenter, 1864. (Pl. 18, fig. 10, Bull. U. S. Nat. Mus., No. 112). "Testa parva, elevata, compacta, fusca; marginibus spirae, excurvatis; anfr. vi., haud tumidis, suturis parvum impressis; lirulis crebis rotundatus undique cincta, quarum v. in spira monstrantur; interstitiis parvis; basi rotundata, haud angulata; umbilico parvo, haud carinato; apertura suborbiculari, parum declivi; columella vix arcuata." (Carpenter). Shell with rounded spiral riblets. Length 6, length of spire 2.75, diameter 5 mm. Known only from Neah Bay, Wash.

*Margarites* (Lirularia) *lacunatus* Carpenter, 1864. "Testa parve, fusco-purpurea, solidiore; marginibus spirae valde excurvatis; anfractibus, postea iv. subplanatis, suturis distinctis, apice mamillato; sublaevi circa basin vixangulatum striolata, striolus spiralibus distantibus; apertura suborbiculari, parum declivi; labio juxta umbilicum constrictum, quasi lacunatum, lobato; columella callositate parva umbilicum constringete." Shell very small, nearly smooth; umbilicus hemmed in by swelling of columella. Length 0.11, long. spir. 0.05, lat. 0.11 of an inch. (Carpenter). Neah Bay, Wash.—Neah Bay, Wash., to San Diego, Calif.

*Margarites* (Lirularia) *parcipictus* Carpenter, 1864. (Plate 47, fig. 2). With rather solid shell, conical, pale darkish purple, somewhat nebulous and spotted; with 5 rotund whorls; with 2 strong (carinal) ridges showing themselves in the whorl, the smaller one intercalary; with subsutural interstices, somewhat weak, obtusely decussate between the ridges; with a peripheral lira well defined, often showing in the spire, with the base strongly rotund; basal ribs about 5, rounded, subdistant; aperture subcircular; columella arcuate; with rather large umbilicus, funnel shaped, not angular. Length, 14; length of spire, 0.7; breadth, 13 mm. (Free translation from Carpenter). San Juan Island, Wash.\*—Sitka, Alaska, to San Diego, Calif.

*Margarites* (Lirularia) *inflatus* Dall, 1920. (*M. inflatus* Carpenter, 1864). Shell thin, whorls very swollen; sculpture very fine; spiral hollow inside keeled umbilicus. (Carpenter). Puget Sound.—Puget Sound and Neah Bay, Wash.

*Margarites* (Lirularia) *lirulatus* Carpenter, 1864. Shell umbilicate, globose-conical, solid, lusterless or slightly shining, purplish, uncolored, or with large radiating white patches above, or around the periphery, or spiral darker lines, or spiral articulated lines. Surface either with (1st.) a few (2-4) strong lirae above, or (2nd) more numerous narrow irregular lirulae above, those of the base still smaller, or (3d) the spiral sculpture obsolete, surface smooth or nearly so above and beneath. The spire is more or less elevated; apex obtuse; suture impressed, sometimes subcanaliculate; body-whorl convex beneath; aperture oblique, oval-rhomboidal, very brilliantly iridescent within, but the acute peristome has a rather broad marginal band of opaque white; columella simple; umbilicus tubular, with incremental striae within. Height, 4-5; diameter, 4-5 mm. (Tryon Manual Conch.) Olga, Orcas Island, Wash., shore; Burrard Inlet, B. C.\*—Port Etches, Alaska, to San Diego, Calif.

*Margarites* (Lirularia) *lirulatus obsoletus* Carpenter, 1864. Shell smaller than the typical, otherwise about the same. Height 3-4, diameter 2-3 mm. False Bay, San Juan Island, Wash., shore, common.\*—Puget Sound to San Diego, Calif.

*Margarites* (Lirularia) *lirulatus conicus* Carpenter, 1864. (Plate 46, fig. 5). Shell very tall, with intercalary ribs, like *M. parcipicta*, (Carpenter).—Known only from Puget Sound and Vancouver Island.

*Margarites* (Lirularia) *lirulatus subelevatus* Carpenter, 1864. Much the same as the typical, raised, livid. (Carpenter).—Known only from Neah Bay, Wash.

*Margarites helycinus* Phipps, 1773. (Fig. 542, Gould's Invert. Mass.) Shell umbilicate, thin, depressed-conoidal, flesh-colored, with paler at periphery and below the suture, fading into corneous around the umbilicus; surface very bright, shining, polished, and smooth except for fine subobsolete concentric lines around the umbilicus; spire conoidal; apex minute but obtuse; suture impressed; whorls about 5, convex, the last very rapidly widening, somewhat descending toward the aperture; aperture rounded, oblique, angular above, nacreous inside, the pearly iridescence often visible through the shell; umbilicus narrow, profound, its opening regularly curved, not separated from the base by a carina. Height, 6; diameter, 7 mm. (Tryon Manual Conch). Roche Harbor, San Juan Island, Wash., in 6 fathoms; Victoria, B. C.\*—Bering Strait to Catalina Island, Calif.; Atlantic.

*Margarites vahlII tenuisculptus* Carpenter, 1865. Closely resembling *M. vahlII* in shape, coloring and in the operculum, but girt with small, more or less obsolete spiral striae of which 4 or 5 are shown on the spire. (A free translation from Carpenter). Puget Sound.\*—Neah Bay and Puget Sound, Wash.

### Family VITRINELLIDAE

VITRINELLA C. B. Adams, 1850

Shell turbiniform, vitreous, minute, with a large, orbicular, aperture; either umbilicated, or with the umbilical region deeply and widely indented. (C. B. Adams).

*Vitrinella columbiana* Bartsch, 1921. Shell moderately large, depressed helicoid, semitranslucent, bluish-white. Nuclear whorls decollated. Postnuclear whorls gently rounded, almost appressed at the summit, marked by rather strong incremental lines which extend over both the upper and lower surface; the lower surface is a little more convex than the upper; the umbilical wall is marked by strong notches. Aperture decidedly oblique, almost circular; parietal wall marked by thin callus, which renders the peristome almost complete. (Bartsch). Altitude, 1.5; greater diameter, 3.1 mm.—Known only from Departure Bay, Vancouver Island.

CYCLOSTREMELLA Bush, 1897

Shell minute, thin, semi-transparent when fresh, planorbiform, of few convex whorls, nearly symmetrically coiled, forming a concavely depressed spire and large umbilical cavity. Epidermis thin,

nearly colorless. Nuclear whorl relatively large, smooth, turned downward, seen only in a basal view, leaving a small pit above. Suture deep and channeled, Aperture triangular-ovate, expanded below, angulated above, with a relatively wide deep sinus just below the suture. Peritreme thin, simple, continuous, not modified, slightly attached. (Bush). Type *C. humilis* Bush, 1897.

*Cyclostremella concordia* Bartsch, 1920. Shell very small, planorboid, hyaline, semitransparent. Early whorls eroded in all the specimens seen. The last 2 whorls curved suddenly to the channeled suture on the upper surface; the rest gradually, evenly rounded. Periphery of the last whorl well rounded. Base openly umbilicated. The entire surface of spire and base is marked by rather strong, irregularly developed incremental lines and more or less equal and equally spaced fine spiral lirations. The intersections of these 2 sculptured elements give to the surface of the shell the characteristic beaded sculpture of the genus. Aperture very broadly ovate, almost subcircular, the narrower portion being at the posterior angle. Operculum thin, corneous, paucispiral. Altitude, 1; diameter, 2 mm. (Bartsch). Olga and Friday Harbor, Wash.\*—Puget Sound.

#### LEPTOGYRA Bush, 1897

This genus is constituted for a group of 3 species of minute, semitransparent, dull, dirty white or faintly brown shells covered with a thin rather tough, delicate straw-colored epidermis, consisting of a few convex whorls forming an elevated spire with relatively large, smooth, slightly twisted nuclear whorl and large body-whorl. Suture deep, somewhat channeled. Umbilicus relatively large, round, deep, showing some of the whorls, with rounded walls. Aperture very oblique, somewhat ovate. Peristome simple, continuous, modified on the body-whorl into a thin glaze, sometimes in the adult having a free edge; strongly sinuate along the umbilical region and anteriorly, slightly angulated below, at the junction of the 2 lips; above arching well upward, forward, then backward from the body-whorl forming a distinct sutural notch. Interior of the aperture smooth and very lustrous, with the conspicuous, exterior, transverse lines showing through by transparency. There is no opaque internal line; in all the specimens the operculum is drawn well into the shell. The operculum is very thin, circular, of a delicate horn-color, with central nucleus of about 7 whorls defined by a fine spiral line. Type *L. verrilli*. (Bush).

*Leptogyra alaskana* Bartsch, 1910. (Pl. 11, figs. 4-6, Nautilus,

vol. 23). Shell minute, depressed helicoid. Nuclear whorls  $1\frac{1}{2}$ , light yellow horn color, marked by faint incremental lines. A single post-nuclear turn follows which is bluish white, rather broad and gently, almost evenly curved from the well-impressed suture to the periphery. This whorl is marked by about 12, fine incised spiral lines between the suture and the periphery which is stronger toward the periphery than at the suture. Periphery of the last whorl rounded. Base broadly and deeply umbilicated, strongly arched, with a slender cord at the junction of the basal and parietal wall, surface of the base marked by incised lines which are equal in strength and number to those occurring upon the upper surface. Wall of the umbilicus almost flat, marked by faint spiral lines. Aperture very large, sub-circular, posterior angle obtuse; outer lip thin; columella curved, somewhat expanded and thickened basally; parietal wall covered with a thin callus. Operculum thin, horny. Height, 0.4; diameter, 0.85 mm. (Bartsch). Olga on Orcas Island, Turn Island and False Bay on San Juan Island, Wash.\*—Port Graham, Alaska, to Puget Sound.

### Family SCISSURELLIDAE

#### SCISSURELLA Orbigny, 1823

Shell minute, thin, not pearly; body-whorl large; spire small; surface striated; aperture rounded, with a slit in the margin of the outer lip; operculate. The young have no slit. (Tryon S. S. Conch.)

*Scissurella kelseyi* Dall, 1905. Shell large for the genus, trochiform, white, with about 4 rounded whorls, sculptured with fine (forwardly convex) arcuate threads or raised lines, which above the fasciole are spirally microscopically striate, and on the base with somewhat regularly spaced and stronger spirals; the fasciole is narrow, slightly above the periphery, bounded by 2 sharp, very thin, elevated keels; the slit extends about one-fifth of the circumference of the last whorl. The aperture is nearly circular, interrupted for a short distance by the body, the inner lip slightly reflected over a small umbilicus; the operculum is multispiral and pale yellow. Alt. of shell, 6; of aperture, 3; maximum diameter, 5.5 mm. (Dall). Queen Charlotte Islands.—Queen Charlotte Islands to South Coronado Island, Lower California.

### Family HALIOTIDAE

#### HALIOTIS Linne, 1758

Shell ovate, ear-shaped, flat; spire small, very short, lateral, peculiarly depressed; pearly and very beautifully prismatic within,

roughly ribbed or wrinkled without, rarely smooth, left side more or less angulated, perforated along the angle by a regular series of holes, some of which are open; left lip inflexed, flattened, right lip simple; aperture very large and wide open. (Conch. Iconica).

*Haliotis kamtschatkana* Jones, 1845. (Plate 47, fig. 1). Shell ovately oblong, spirally striated and ridged, ridges flatly obtuse, rather distant, transversely obliquely full of conspicuous waved swellings, left side rather broadly grooved, perforations rather swollen, large, 4 only open; exterior tessellately variegated with bright red and green, spiral ridges articulated with red. Length, 96; breadth, 67; convexity, 22 mm. (Conch. Iconica). Outer coast of Vancouver Island, B. C., by Rev. G. W. Taylor.—Kamchatka Sea to Redondo, Calif.; Japan.

### Family FISSURELLIDAE

#### MEGATEBENNUS Pilsbry, 1890

Shell not white-bordered above. Edges of shell elevated at each end, blunt at the sides, in adults not crenulated. (Pilsbry).

*Megatebennus bimaculatus* Dall, 1871. (Pl. 15, fig. 7, Amer. Journ. Conch., vol. 7). Shell ellipsoidal when young, subquadrangulate, and a little narrower in front than behind, when adult. Aperture the same shape as the shell, slightly encroached upon in some specimens by a point on each side. External surface furnished with radiating, rounded costae, not bifurcating but widening slightly toward the margin. These are crossed by evident but not very strong lines of growth, which, in some individuals, are rather strong. Anterior declivity of the shell concave, sides flattened, posterior declivity rounded convex. Color whitish, with numerous radiating rays of brown or slate color, usually with a broad fasciculus of darker rays in the middle of each side extending from the apex to the margin, and occasional dark dots on the ribs. Shell occasionally entirely brown or slate color, with 2 darker rays on the sides. Epidermis none. Interior pure white, the 2 dark rays sometimes showing through the shell. Extreme outer edge finely denticulate or rounded and smooth according to the stage of growth. Margin as a whole broad, smooth, differentiated from the rest of the surface by a wide, shallow groove. Margin of the aperture similarly bordered. Muscular impressions distinct, surface marked by fine radiating lines; polished. Anterior and posterior margins internally concave or emarginated, so that when laid upon a flat surface in the natural position the ends of the shell do not touch it. Length, 0.7; breadth, 0.5; height, 0.2 of an inch. (Dall).

Vancouver Island.—Forrester Island, Alaska, to Cape San Lucas, Lower California.

DIADORA Gray, 1821. (Glyphys; Fissuridea)

Shell ovate conical; orifice anterior to the center, elliptical. Surface cancellated by radial ribs and concentric growth lines. Internal callus around the orifice heavy and slightly truncated behind. Interior of shell smooth; margins crenulated.

*Diadora aspera* Eschscholtz, 1833. (Plate 11, fig. 1). Shell ovate, narrower in front, conical, the slopes nearly straight or a little convex behind the middle. Sculptured with numerous radiating riblets of which 30-34 are larger, the intervals between them bearing about 3 smaller ones; the whole decussated by close elevated concentric lirae, which are more or less scale-like and imbricating. Color soiled whitish, with numerous wide blackish rays. Inside white, hole callus white, very abruptly truncated behind; margins deeply and sharply crenulated. Perforation short-oval, nearly circular, in front of the middle. Length, 56; width, 40; height, 18 mm. (Tryon Manual Conch.) San Juan Island, Wash.; Departure Bay, B. C.\*—Cook Inlet, Alaska, to Magdalena Bay, Lower California.

PUNCTURELLA Lowe, 1827

Shell conical, having a spirally recurved apex either persistent or absorbed in the adult, the fissure either lanceolate or oval, on the front slope or at the summit of the cone; inside there is a plate extending forward forming a conduit to the fissure or a deck over it. The spiral apex is inclined toward the right side, and the fissure is also a trifle to the right of a median line, when visibly excentric. The surface usually shows minute granules under a strong magnification. (Tryon Manual Conch.) Type *P. noachina* Linne.

*Puncturella galeata* Gould, 1846. (Plate 11, fig. 3). Shell solid, ashy-white, erect, elevated conic, with the outline somewhat convex; the apex central, elevated, acute, and reaching forwards and upwards. Surface radiated with numerous nearly equal raised lines, which are decussated by much finer concentric striae; fissure small. Aperture rounded-oval, the margin expanded and thinned to a sharp edge, which is minutely crenulated. The fornix is circularly arched over a short sulcus, and in front of it, near the summit, runs a transverse rib, leaving between it and the fornix, on either side, a triangular pit. The summit also appears to be filled with callus. Colour greenish-white within. Length, 0.45; breadth, 0.40; height, 0.40 of an inch.

(Gould). Off San Juan Island, Wash., in 20-30 fathoms; Departure Bay, B. C.\*—Unalaska, Alaska, to Santa Rosa Island, Calif.

*Puncturella cucullata* Gould, 1846. (Plate 11, fig. 4). Shell rather solid, ovate at base, and rising to form an elevated, oblique cone, having the apex at the posterior fourth of the shell, so that the anterior slope is moderate, while the posterior slope is nearly vertical. The apex is prominent, acute; reaching forwards like a curved beak. The color is dirty cinerous. The surface is radiated by sharp, prominent, compressed ribs, which are alternately larger and smaller, to the number of about 40; and these are crossed by very fine and crowded concentric lines, by which they are delicately muricated. Fissure narrow, and narrowing upwards. The interior is porcelain-white; the edge is beautifully crenulated by regular furrows, alternately longer and shorter, deeper and shallower, answering to the external ribs. The fissure is rounded, and the vault enclosing it is thin, simple, semicircular, and without callus at the summit. Length,  $\frac{5}{8}$ ; breadth,  $\frac{7}{16}$ ; height,  $\frac{3}{8}$  of an inch. (Gould). Off San Juan Island, Wash., in 25 fathoms; Victoria, B. C.\*—Kodiak Island, Alaska, to La Paz, Lower California.

*Puncturella multistriata* Dall, 1902. (Plate 11, fig. 2). Shell with small, slightly alternated, rather close set radial threads. This has generally been associated with *P. cucullata* as an extreme variation. Length, 27; breadth, 18; height, 16 mm. (Dall). Off San Juan Island, Wash., in 20-30 fathoms.\*—Aleutian Islands, Alaska, to San Diego, Calif.

*Puncturella cooperi* Carpenter, 1864. Shell almost exactly like *P. galeata*, but the internal plate solid, plane, scarcely anteriorly sinuate, scarcely propped. Outside like *P. noachina*, but with the lamina like *P. cucullata*, without eye-holes (accessory lateral pits). The latter species is extremely variable in sculpture but never so fine as this; and the shape is less conical. Height, 0.24; diameter, 0.21 mm. (Tryon Manual Conch.) Departure Bay, B. C., by Dr. C. M. Fraser.\*—Kasaan, Alaska, to San Pedro, Calif.

*Puncturella major* Dall, 1891. (Pl. 26, fig. 4, Proc. U. S. Nat. Mus., vol. 17). Shell resembling *P. galeata* in general and especially in the interior, but very much larger; radii alternately large and small from the beginning; shell white; anterior slope rectilinear, posterior slope slightly arched and a little longer; internal margin crenulate. Length, 57; breadth, 42; height, 27 mm. (Dall). Dixon's Entrance.—Bering Sea to Dixon's Entrance, Alaska.



## CLASS AMPHINEURA

## Family LEPIDOPLEURIDAE

## LEPIDOPLEURUS Risso, 1826

Insertion plates absent. Girdle with minute, gravelly, smooth or striated scales, usually with a marginal fringe of longer scales. (Tryon Manual Conch.) Type *L. cajetanus* Poli.

*Lepidopleurus cancellatus* Sowerby, 1839. (Pl. 3, figs. 54-58, Tryon & Pilsbry's Manual Conch., also figs. 104, 105, Sowerby's Conch. Illust. Chiton). Shell small, elongated, much elevated, regularly arched, not angled. Orange-ashen or whitish. Anterior valve radiately, evenly, very finely granose-lirate. Central areas of the intermediate valves having distinct longitudinal, fine, close granulose lirae, the granules being sometimes arranged in transverse lines also, giving a latticed appearance; lateral areas distinct, decidedly raised, convex, having radiating but rather irregular rows of granules. Posterior valve with central elevated apex; posterior slope concave. Interior white, the sutural plates small, triangular; jugal sinus very broad. Girdle narrow, densely beset with delicate, scarcely imbricating or striated, scales. Length, 5.5; breadth, 2.5 mm. (Tryon Manual Conch.) Victoria, B. C., by Dr. C. F. Newcombe.\*—Bering Strait to Oregon; Atlantic.

*Lepidopleurus luridus* Dall, 1902. Chiton small, solid, narrow, of a lurid smoky color, darker on the lateral areas; girdle densely pilose, with whitish spicules; back rounded, with the jugum defined feebly, most conspicuous as a distinct mucro, mesially, on the intermediate valves; pleural areas divided by obscure depressed lines radiating from the mucro to the inner edges of the pleural laminae; lateral areas prominent, more or less concentrically rugose; anterior valve simple, normal; posterior valve with a conspicuous central mucro, behind which it is more or less concave; the whole surface is covered with minute, quincuncially arranged pustulation; on the intermediate valves the pustules on the lateral and pleural areas appear to diverge from the inner margin of the lateral areas; internally there is a wide unattached margin on the under side of the posterior edge, mesially, in the intermediate valves; the pleural laminae are short and all the valves callous internally, with the points of attachment to muscles and girdle impressed; there is no linear arrangement of the pustules on the jugum; the ctenidia only reach the seventh valve.

Lon. of animal about 16; lat. 6; alt. 3 mm. (Dall). Puget Sound.—Puget Sound, in 48 fathoms; Panama, in 1270 fathoms.

### Family LEPIDOCHITONIDAE

#### LEPIDOCHITONA Gray, 1821

Valves, sutural plates, sinus and teeth as in *Ischnochiton*, but the eaves are spongy; girdle as in *Tonica*, leathery, smooth or nearly so. Gills extending forward from  $2/3$ – $3/4$  the length of the foot. (Tryon Manual Conch.) Type *Chiton marmoreus* Fabricius.

*Lepidochitona submarmorea* Middendorff, 1846. (Pl. 14, figs. 7, 10; and pl. 15, figs. 7, 8, Middendorff's *Sibirische Reise*). Shell oval, rather depressed, rather smooth and shining, the entire surface seen under a lens to be very minutely, regularly and closely granulose. Lateral areas scarcely distinct, slightly swollen. Color rosy or yellowish-white, closely painted with spots and flames of red. Interior rose colored; terminal valves with 5 slits. Girdle smooth, shining, yellow or brown. Length 38, breadth 24, height 12-13 mm. (Tryon Manual Conch.) San Juan Island, Wash.\*—Aleutian Islands to Puget Sound and Japan.

*Lepidochitona lineata* Wood, 1815. (Pl. 2, figs. 4-5, Wood's General Conch.) Shell oblong, rather low, roundly arched or subcarinated. Surface smooth, shining, ground color light reddish. End valves concentrically marked with black-brown lines bordered above with white, intermediate valves having similarly colored longitudinal lines, sloping obliquely backward, the ridge or jugum of each valve having a light triangle with a narrower dark one in the middle on some valves. Occasionally some valves are wholly dark brown, unmarked. Lateral areas scarcely raised; umbo of posterior valve in front of the middle. Interior white, more or less tinged with rose color. Sutural plates broad, rounded; sinus deep and angular. Anterior valve with 8-10, median 1, posterior valve 8-10 slits. Teeth short, especially in the posterior valve, and blunt, in adults decidedly crenulated at the tips and obsoletely fissured outside. Eaves small. Girdle leathery, apparently smooth and nude, brown in dried specimens. Length, 37; breadth, 20 mm. (Tryon Manual Conch.) General on all the islands of the San Juan group.\*—Aleutian Islands to San Diego, Calif.; Okhotsk Sea; northern Japan.

*Lepidochitona ruber* Linne, 1767. (Pl. 7, figs. 50-56, Tryon & Pilsbry's Manual Conch., vol. 14; also pl. 15, fig. 25, vol. 15). Shell oblong, elevated, solid, the back roundly subangular, lateral slopes

somewhat convex; surface apparently smooth except for well-marked grooves or wrinkles, indicating growth-periods. Under the microscope, however, an excessively fine reticulation is visible. The color is light buff, marbled all over with orange-red in various patterns, or entirely suffused with reddish; usually having a red dorsal stripe bordered on each side with buff. The anterior valve is twice as long, crescentic rather than half-round. The intermediate valves are slightly beaked, their lateral areas slightly raised and having stronger concentric wrinkles than the central areas. Posterior valve having a rather elevated but obtuse median umbo. The interior is a bright pink. The sutural plates are wide, large; the jugal sinus is deep, narrow and angular. The insertion plate of the anterior valve has 8-10 slits; intermediate valves normally 1 slit; posterior valve 7-11 slits. The insertion plates are sharp and smooth. The girdle is reddish-brown, covered with minute elongated scales. The gills extend forward to the middle of the body. Length 20, breadth 12 mm. The Alaskan species grow to the length of 25 mm. Arctic Ocean to Monterey, Calif.; circumboreal.

*Lepidochitona dentiens* Gould, 1846. (Fig. 433, Gould's Mollusca and shells of the U. S. Explor. Exped., 1852; under Wilkes. Also pl. 15, fig. 26, Tryon & Pilsbry's Manual Conch., vol. 15). Shell oval, rather elevated, dorsally angled, ash colored, closely and finely mottled with olive, and having a series of alternating olive and light spots upon the back edges of the valves along the sutures. These spots are often obscure or wanting, and in some specimens the ground color is pale orange-flesh tint. The valves are covered with a very minute sharp granulation, the granules small but well raised, and on the central areas of some specimens they are somewhat disposed to be arranged in longitudinal lines converging toward the dorsal ridge, this disposition usually stronger toward the lateral extremities of the valves. The lateral areas are a little raised, the diagonal lines separating them from the central areas rather distinct. The umbo of the posterior valve is median, somewhat raised, the slope behind it being depressed and concave. The interior is either whitish stained with gray-green, or quite green. The sutural plates do not project as far as usual, and on some valves they are emarginate in front. The jugal sinus is wide, angular, flat or encroched upon by the jugum. The anterior valve has 11 slits in the insertion plate, the intermediate valves 1, the posterior valve 10-12, and some of the median teeth are bifid at the tip. The girdle is narrow, gravelly, covered with minute scales. Length 15, breadth 10 mm. Puget Sound.—Puget Sound to Socorro Island, off Mex.

*Lepidochitona alba* Linne, 1767. (Pl. 7, figs. 35-38, Tryon & Pilsbry's Manual Conch., vol. 14). Shell oblong, elevated, the back keeled, lateral slopes nearly straight. Anterior valve half-circular, its posterior margin slightly concave; sculpture consisting of some scarcely perceptible, low radiating ridges, often wholly obsolete, and an excessively minute shagreening or granulation of the whole surface, the granules showing a disposition to be arranged in oblique curved lines. Intermediate valves slightly beaked, produced forward in the middle, having the same sculpture, and showing low, irregular growth wrinkles. Lateral areas scarcely raised, sculptured like the front valve. Posterior valve having the umbo slightly elevated, central, inclined backward. Interior white. Sutural plates large and wide, extending from the insertion plates nearly to the jugum. Sinus rounded. The anterior valve has 13 slits in the smooth and rather sharp insertion plate; the intermediate valves have one slit; the posterior valve has 10 slits, and the edge of the plate is decidedly roughened and irregular. Another specimen has 14 slits in the anterior valve, 12 in posterior valve; and in still another individual, some of the intermediate valves have 2 slits on one side. The girdle is covered with small gravelly scales, and has no marginal fringe of long scales or spines. The color is a very delicate buff tint, sometimes almost white, often shading into a light orange on the posterior part and lateral areas of each valve. Most specimens have more or less of a black deposit on the back part of the valve. Length, 15; breadth, 7 mm. (Tryon Manual Conch.) Puget Sound.\*—Arctic Ocean to San Diego, Calif.; circumboreal.

*Lepidochitona flectens* Carpenter, 1864. (Pl. 15, figs. 34-37, Tryon & Pilsbry's Manual Conch., vol. 15). Shell small, subelongate, roseate; jugum acute; lateral areas scarcely defined. Valve margins excurved, suture incurved, apices very prominent; valves having minute, not very close granules sparsely subradiating, all over very minutely punctulate. Mucro conspicuous, anterior. Inside sutural sinus wide, flat, eaves scarcely projecting. Terminal valves with 11, median 1 slit. Girdle very minutely granulate. "This is the original description." Length 8.75, breadth 6 mm. (Tryon Manual Conch.) Puget Sound.\*—Vancouver Island to San Diego, Calif.

*Lepidochitona hartwegii* Carpenter, 1855. (Pl. 14, figs. 81-85, Tryon & Pilsbry's Manual Conch., vol. 14). Shell oval, rather low, the dorsal ridge obtusely rounded; dull olive green, generally having a pair of lighter stripes on the ridge of each valve with a black blotch outside of the light dashes. Girdle rather narrow, dense, microscop-

ically closely granulated. The tail valve is convex as a whole, but the subcentral umbo is not conspicuous. The entire surface is very closely microscopically granulated, and bears larger wart-like granules irregularly scattered over the minute sculpture, these warts being much more numerous upon the lateral areas (which are otherwise rather ill-defined) and the terminal valves. The interior is of an intense blue-green color. Sutural plates rounded, leaving a wide, angular sinus. Insertion plates shorter than the eaves, blunt, the anterior valve having the teeth 2-3-lobed, the posterior valve having them crenulated. Slits of anterior valve 10-11; median valves 1; posterior valves 9-12. Eaves spongy. Length, 30; breadth, 17 mm. (Tryon Manual Conch.) General on all the islands of the San Juan group.\*—Forrester Island, Alaska, to Gulf of California.

*Lepidochitona hartwegii nuttallii* Carpenter, 1855. Umbo flatter; valves broad, non-swelling, squared at the sides and not beaked or waved. Posterior valve having 11, central 1, anterior 8 slits. (Tryon Manual Conch.) It is a longer shell than the typical, and narrower. Strait of Fuca.—Strait of Fuca to Turtle Bay, Lower California.

*Lepidochitona raymondi* Pilsbry, 1894. Shell longer and narrower than *L. hartwegii*. Back somewhat keeled, varying in elevation. Color (1) olivaceous green mottled with white, sometimes with dark lateral streaks as in *L. hartwegii*, sometimes ruddy at the ridge, or (2) uniform blackish, or (3) dark brown, uniform or with whitish flecks. Valves rather strong, slightly beaked when unworn, the posterior (sutural) margins straight or slightly concave. Intermediate valves rather rounder where they join the girdle, scalloping the inner border of the latter; not distinctly divided into areas. Lateral areas hardly or not raised (the diagonal being indistinct) evenly sculptured with minute, equal granules. Central areas also evenly sculptured throughout with similar granules, slightly finer on the ridge. End valves with the same equal sculpture, the tail valve with the mucro central and a little projecting. Interior light blue, with darker stains at bases of the sutural laminae and behind the rather strong blue-white valve callus. Sipus and sutural laminae as in *L. hartwegii*. Slits in valve i, 8; valves ii-vii, 1-1; valve viii, 11; teeth of end valves blunt, thick, but not distinctly bilobed. All teeth longer than narrow, porous eaves. Girdle narrow, black or with small whitish spots, leathery, very minutely papillose. Length, 23; breadth, 11 mm. (Pilsbry). Puget Sound.\*—Seward, Alaska, to San Diego, Calif.

## NUTTALLINA Carpenter, 1873

Valves exposed, granulated, having long smooth sharp teeth; the slits of the median valves obsoletely doubled, those of the anterior valve corresponding in position to the external ribs, the teeth not thickened at the edges of the slits; mucro of posterior valve posterior, terminal but not marginal; teeth of posterior valve short, chisel-shaped, directed forward. Eaves and sinus spongy. Girdle bearing short, rigid spines. (Tryon Manual Conch.) Type *N. californica* Reeve (*N. scabra californica* Nuttall).

*Nuttallina californica* Reeve, 1848. (Pl. 16, fig. 20, Reeve's Conch. Icon., as *Chiton*; also pl. 54, figs. 23, 24, and pl. 56, figs. 12-18, Tryon & Pilsbry's Manual Conch., vol. 14). Shell elongated, more than twice as long as wide, moderately elevated, carinated or somewhat rounded. Surface finely corrugated-granular, lusterless; color dark brown, dark olive-brown or blackish, unicolored or having 1 or 3 whitish stripes along the summit of the second valve. Median valves strongly beaked v-shaped, the anterior margin of the tegmentum trilobed; having a smooth shining rounded dorsal ridge (sometimes obsolete and often eroded), bounded by a pair of diverging, shallow furrows; the entire sides of the valves (pleura and lateral areas) closely granulated, the granules irregularly arranged in rows. Lateral areas not raised but indicated by a low curved diagonal rib, behind which and parallel to it, there is a shallow sulcus. Anterior valve having 11 low rounded radiating ribs, the entire surface granulated. Posterior valve depressed, small, the muscro posterior and terminal, projecting beyond the posterior margin of the eaves. Interior bluish, sometimes stained with blackish at jugum and bases of the sutural plates. Sutural plates very long, separated by a wide, deep, square sinus; behind which is a punctate and laminate area. Anterior valve having 11 or 10, median valves with 2 slits, or at least 2 punctulate slit-rays, the posterior slit being usually indistinct or wanting from the more or less complete obsolescence of the posterior tooth; teeth sharp, smooth, long, not thickened at the edges of the slits. Posterior valve having 8-9 slits, the teeth chisel-shaped, sharp, smooth, very strongly directed forward. Eaves narrow, spongy. Girdle closely covered with short, rigid calcareo-corneous spinelets, mostly of a scorched brown color with a few white spines intermingled. Length, 37; breadth, 15 mm. (Tryon Manual Conch.) Vancouver Island, B. C.—Vancouver Island, B. C., to San Diego, Calif.

**Family ISCHNOCHITONIDAE****ISCHNOCHITON Gray, 1847**

Valves external, having sharp, slit, insertion plates, the teeth not buttressed. Eaves solid (rarely somewhat porous in s. g. *Trachydermon*); girdle covered with imbricating scales, either flat or convex, smooth or striated. (Tryon Manual Conch.)

*Ischnochiton* (*Stenoplax*) *fallax* Carpenter, 1892. (Pl. 16, figs. 17, 18, Tryon & Pilsbry's Manual of Conch., vol. 14). Almost exactly like *Ischnochiton magdalenensis* in form and sculpture, but more roseate; the central areas pitted; lateral areas having close radiating wrinkles interrupted by lines of growth. Interior: posterior valves having 9, central 1, anterior 10 slits; teeth acute; eaves conspicuous; sinus moderate, scarcely laminate, but the jugal part of the valves produced forward. Girdle having very minute granules. Length, 27.5; breadth, 12.5 mm. (Tryon Manual Conch.) Vancouver Island.—Vancouver Island to Todos Santos Bay, Lower California.

*Ischnochiton retiporosus* Carpenter, 1864. (Pl. 16, figs. 47, 50-53, Tryon & Pilsbry's Manual Conch., vol. 15). The shell is rather elevated, distinctly carinated, the side-slopes nearly straight. The color is either (1) dull buffish gray white touched with reddish orange at each beak, or (2) a very pretty shade of reddish purple, uniform or with a white dorsal stripe and some faint light sports; in either case the girdle is of the same color as the valves, with or without black scales scattered over it. The valves are partially covered by a black deposit in all of the individuals seen. The slight beaks of the median valves do not modify the slight concave contour of the posterior border. The lateral areas are not raised; sculpture consisting of a variable number (generally 4-7) of rather acute radiating riblets (spreading somewhat like those of a Pinna) bearing sparsely scattered, minute pustules which are often lacking on some or all valves; the intervals between riblets finely granulated. Central areas sculptured with very beautiful and clearly-cut pattern of squarish pits or cells formed by the crossing of fine forward-converging riblets by others curving in a radical direction. Anterior valve having many narrow radial riblets, like those of the lateral areas, some of them generally with minute pustules. Posterior valve having the mucro in front of the middle. Interior bluish-white or pink. Anterior valve having 11, median valves 1-1, posterior valve 11 slits. Sutural laminae low and rounded, continuing in a narrow lamina across the shallow, wide, gently rounded sinus. Girdle covered with solid rather flattened scales measuring

about one-sixth of a mill. in breadth, and coarsely, deeply striated. Length, 15; breadth, 8 mm. (Tryon Manual Conch.) Victoria, B. C., by Dr. C. F. Newcombe; Turn Island, San Juan County, Wash.\*—Victoria, B. C., to San Pedro, Calif.

*Ischnochiton retiporosus punctatus* Whiteaves, 1886. (Figs. in Trans. Roy. Soc. Canada, vol. 4, pt. 4). Sculpture as in *retiporosus*, but the riblets of end valves and lateral areas are more delicate, subobsolete; and the network of the central areas is shallower. Color pale cream, nearly white, with a spot of orange-brown on the ridge of valves ii to viii, and a few irregular spots of reddish on the white girdle. Length about 8 mm. (Tryon Manual Conch.)—Known only from Discovery Passage, at Duncan Bay, Vancouver Island.

*Ischnochiton interstinctus* Gould, 1846. (Pl. 23, fig. 423, Gould's Mollusca and Shells of the U. S. Explor. Exped., 1852; under Wilkes). Shell oval-oblong, rather elevated, the dorsal ridge obtusely keeled, side slopes nearly straight. Surface apparently smooth, but under a lens it is seen to be very minutely punctulate, the indistinct lateral areas being obsoletely radiately lirate also. Dark reddish, mottled with light on the dorsal ridge. The lateral areas are scarcely perceptibly raised and besides being microscopically punctate like the rest of the surface they have low radiating ribs, about 6 or 7 in number. Central areas evenly punctulate; end valves punctulate and radiately multi-lirate. Umbo of posterior valve with 12, anterior valve 10, median valves 1 slit; teeth acute, eaves moderate; sinus wide, flat. Girdle densely covered with small, suboval, delicately striated scales. Length, 15; breadth, 8 mm. (Tryon Manual Conch.) Puget Sound.\*—Aleutian Islands to Catalina Island, Calif.

*Ischnochiton radians* Carpenter, 1892. (Pl. 16, figs. 48, 49, Tryon & Pilsbry's Manual Conch., vol. 15). Shell rather large, wide, elevated, the jugum acute; olivaceous, elegantly radially streaked with brown. Interior blue-green with 2 brown rays. Valves delicate, flat, produced in the sinus in front of the middle, scarcely elevated; entire surface quincuncially granulated; lateral areas scarcely defined, and with the end valves obsoletely sublirulate. Interior: posterior valve having 9-10, central valves 1, anterior valve 10-11 slits; teeth acute; eaves small; sinus wide, short, scarcely laminate. Girdle regularly covered with solid, coarsely striated, moderate sized scales. Length, 21; breadth, 15 mm. (Tryon Manual Conch.) Puget Sound.—Prince of Wales Island, Alaska, to San Pedro, Calif.

*Ischnochiton mertensii* Middendorff, 1846. (Pl. 26, figs. 20-26, Tryon & Pilsbry's Manual Conch., vol. 14). Shell oval, elevated, with



angular dorsal ridge, and straight side slopes. Varying in color from orange-red to claret-red, or even dark red-brown, and either unicolored or speckled and blotched with white. The lateral areas are elevated, and sculptured with radiating rows of elevated pustules standing upon a smooth, almost flat ground; the pustules of the sutural row often irregular. Central areas having acute, narrow, parallel raised riblets, the intervals between them regularly latticed across, except at the dorsal ridge, where the riblets have a tendency to diverge, and the cross, low, flat and inconspicuous. Interior white or blue-white, the median valves when detached showing broad red-brown rays posteriorly, the end valves with crescents of the same color. Sutural plates low; sinus flat, angular, finely toothed. Anterior valve having 10-11, central valves 1, posterior valve 10 slits; teeth rather short and obtuse, and usually distinctly roughened; eaves rather wide. Girdle firm, compactly covered with regular, solid, oval, shining scales, which are usually smooth, but frequently are superficially or obsoletely striated. Length, 35; breadth, 21 mm. (Tryon Manual Conch.) General on all the islands of the San Juan group.\*—Sitka, Alaska, to San Pedro, Calif.

*Ischnochiton willetti* Berry, 1917. (Figs. 1, 2, Proc. Calif. Acad. Sci., ser. 4, vol. 7, p. 236.) Shell rather large, regularly elliptically elevated, with an angular dorsal ridge and arcuate side slopes. General surface indistinctly granulose. Anterior valve with 35-45 low, occasionally bifurcating, radiating ribs, separated by shallow, distinct grooves and bearing a variable number (normally 8-10) of small well separated, distinct, rounded pustules. Median valves: lateral areas distinctly raised, sculptured like the anterior valve, but the 5-7 ribs relatively wider and more flattened, the defining grooves sometimes, but not always, sharply chiseled; central areas on each side sharply sculptured with 20-25 narrow, faintly beaded, longitudinal ridges, their interstices traversed by low, rather irregular cross-ridges, becoming nearly or quite obsolete at the jugum. Posterior valve with mucro well in front of center; region behind mucro sculptured like the anterior valve, but the 28-30 ribs rather less distinct and the grooves less conspicuous; region in front of mucro sculptured like central areas of the intermediate valves. Interior of central valves thickened across the middle. Teeth with a distinct fossa separating them at base from body of shell, their edges roughened, those of the posterior valve almost crenate. Anterior valve with 11, second valve with 2-1, third to seventh valves with 1-1, posterior valve with 12 slits. Girdle wide, regular; covered dorsally with a closely imbricating armature of large, smooth or barely striated convex scales, each normally bear-

ing a short, striated, nipple-shaped process projecting upward from the dorsal end. Color of outer surface of shell a reddish brown of varying intensity in different specimens, sometimes nearly black; girdle lighter. Interior of shell light salmon. Length, 29.5; width, 16 mm., of largest specimen. (S. S. Berry). Off Forrester Island, Alaska, in 15-20 fathoms; Puget Sound.\*—Forrester Island, Alaska, to Puget Sound.

*Ischnochiton clathratus* Reeve, 1847. (Pl. 18, fig. 113, Reeve & Sowerby's Conch. Iconica, *Chiton*; also pl. 26, figs. 31-34, Tryon & Pilsbry's Manual Conch., vol. 14). Shell oval or oblong, elevated, the back carinated; side slopes straight; lateral areas and end valves radially granulate-lirate, central areas latticed. Color dingy yellow, clouded with black, or rarely unicolored yellow or olivaceous. Lateral areas are raised and sculptured with about 5 radiating, closely and conspicuously granose riblets, the posterior rib wide or bifid; strongly pectinated along the sutural edge. Central areas having longitudinal narrow bars parallel to the dorsal ridge, decussated by bars of almost equal prominence vertical to them, producing the effect of a grating. Mucro depressed. Interior whitish, with olive or leaden rays under the umbones. Sinus flat, denticulate; anterior valve having 11-12, central valves 1, posterior 14-16 slits; teeth rather sharp, but not thin, eaves solid. Girdle compactly covered with very convex scales, which are quite obsoletely striated. Length, 27; breadth, 17 mm. (Tryon Manual Conch.) San Juan Island, Wash.\*—Puget Sound to La Paz, Lower California.

*Ischnochiton triffidus* Carpenter, 1864. (Pl. 18, fig. 40, Tryon & Pilsbry's Manual Conch., vol. 14). Shell rather large, rather elevated, regularly oval; red-chestnut, maculated with lighter and darker; jugum acute, gothic. Mucro median, flat; entire surface minutely granulated; central areas having about 8 strongly punctate lines perpendicular to the jugum; lateral areas strongly defined, having 2-4 obsolete ribs, sometimes punctate in the interstices. Interior whitish flesh-colored, with 2 reddish-purple rays diverging from the flat umbones; posterior valve having 13, anterior 13, central valves 2 slits; teeth acute, sometimes serrated at the edge, sometimes striated outside, sometimes smooth. Eaves subspongy; sinus small, laminate, the lamina slit at the sides and sometimes in the middle. Girdle having very small, solid, smooth scales. Length, 40; breadth 26 mm. (Tryon Manual Conch.) Puget Sound.\*—Shumagin Islands, Alaska, to Puget Sound.

## CALLISTOCHITON Carpenter, 1882

Valves conspicuously sculptured; the insertion-plates short, smooth or nearly so, festooned, being curved outward at the ribs and slit there, thickened outside at the edges of the slits, the latter corresponding in position to the ribs of the outer surface. Sinus squared. Mucro median or post median, generally depressed. Girdle poreless, densely clothed with minute striated or smooth scales. (Tryon Manual Conch.) Type *Chiton pulchellus* Gray.

*Callistochiton crassicostatus* Pilsbry, 1892. (Pl. 58, figs. 1-6, Tryon & Pilsbry's Manual Conch., vol. 14). Shell oblong, elevated, the dorsal ridge very obsoletely angular, side-slopes arched. Surface lusterless, green or brown. Valves not beaked, the lateral areas extremely prominent, unevenly granulated, the concentric riblets being cut by one or several radiating grooves. Central areas having strong longitudinal bars, converging  $\Lambda$ -like on the ridge (even on the second valve), the intervals very closely and finely latticed across. Anterior valve having 7 very strong ribs, each divided by a shallow median groove. Posterior valve elevated, having the mucro directly over the posterior edge, the hinder area not higher than the area in front of it; posterior slope vertical, convex, sculptured with 5 very strong, deeply separated ribs, which are granose above, and subdivide into several riblets each toward the lower margin. Interior bluish-white; sutural-plates slightly connected across the rounded sinus. Anterior valve having 9, central valves 1, posterior valve 13-20 slits; teeth short, rather sharp and smooth, hardly projecting below the eaves, thickened along the slits outside; eaves broad, solid. Girdle narrow, thin, covered with excessively minute, closely imbricating, striated scales. Length, 22; breadth, 9 mm. (Tryon Manual Conch.) Puget Sound.—Forrester Island, Alaska, to San Diego, Calif.

*Callistochiton aepynotus* Dall, 1919. Chiton yellowish white, with a keeled back, the girdle as usual in the group; anterior valve with 10 annulate ribs and a slit for each rib; posterior valve small, low, with only about 5 feeble ribs, and 5 slits, the central area reticulate; intermediate valves with a narrow smooth line at the jugum, and single slits; the pleural tracts sharply obliquely reticulate with deep interspaces; the lateral areas bounded by 2 strong annulate ribs, the posterior rib wider, the interspaces regularly punctate-reticulate; interior white, the jugal sinus almost obsolete. Length, 15; width, 7; height, 5 mm. (Dall).—Known only from Puget Sound.

**Family MOPALIIDAE****MOPALIA Gray, 1847**

Chitons in which the valves are divided in the normal manner into the lateral and central areas; the teeth of insertion are not pectinated; and the posterior valve has a posterior-median sinus, with one slit on each side or none. The girdle is more or less hairy, never scaly. Gill row as long as the foot. The normal number of slits in the anterior valve is 8; but this is often increased or diminished by splitting or fusion of 1 or 2 teeth. The slits correspond in position to external ribs, as in the last subfamily. The girdle clings more tenaciously to the teeth than in most chitons. It is frequently provided with pores at the sutures, each pore generally bearing 2 or several bristles or hairs; but the presence or absence of these pores is in no case of more than specific value, and in some cases I have found it to be a mutable feature among individuals of the same species. (Tryon Manual Conch.)

*Mopalia ciliata* Sowerby, 1840. (Fig. 79, Sowerby's Conch. Illustr.) Shell oblong, rather depressed, the dorsal ridge carinated (sometimes rounded), side-slopes straight or somewhat convex. Surface lusterless, finely sculptured, variously colored, usually either (1, typical coloring) verdigris green maculated with black or black-brown, the girdle yellow or (2) maculated with maroon and sometimes touched with rich chestnut on the ridge, or having some valves or parts of valves vivid scarlet, or scarlet mixed with olive and snow-white, or entirely white; or (3) light olive-buff with brownish girdle. Valves somewhat beaked, the lateral areas bounded by a riblet, rather coarsely granulated, with larger granules along the posterior margin. Central areas sculptured with longitudinal, curving riblets somewhat granulated, much closer and finer on the dorsal ridge. Anterior valve having granose narrow radii, the intervals granulated. Posterior valve small, with posterior mucro, broadly emarginate or waved at the hinder margin. Interior bluish-white or light blue-green. Sinus broad and rather rounded, spongy or roughened. Suture plates arcuate. Anterior valve having 8 slits, median valves 1 slit. Posterior valve having a broad deep, rounded caudal sinus, and a single slit on each side. Girdle wide, yellow or brown, generally notched behind, more or less sparsely clothed with curling strap-like brown hairs, which bear near their bases a bunch of minute, white, acute spines. Length, 46-50; breadth, 25 mm. (Tryon Manual Conch.) San Juan Island, Wash.\*—Vancouver Island to Lower California.

*Mopalia ciliata wosnessenskii* Middendorff, 1847. (Pl. 64, figs. 69-73, Tryon & Pilsbry's Manual Conch., vol. 14). Shell elongated, the back roundly arched, not carinated; dull colored, varying from light olive or green to drab, generally with blackish patches on each side of the middle, and more or less mottled throughout with dusky. Sculpture much fainter than in typical *ciliata*. Girdle apparently lacking the white spicules described above. Length, 40-45; breadth, 25 mm. (Tryon Manual Conch.) San Juan Island, Wash.\*—Unalaska, Alaska, to Santa Rosa Island, Calif.

*Mopalia ciliata elevata* Pilsbry, 1892. (Pl. 64, figs. 82, 83, Tryon & Pilsbry's Manual Conch., vol. 14). More elevated, acutely carinated, more or less pitted superficially and either painted with the pattern, on a white, creamy or green ground, or having concentric zig-zag blackish streaks. Interior is bright blue. Puget Sound.—Forrester Island, Alaska, to Puget Sound.

*Mopalia muscosa* Gould, 1846. (Fig. 436, Gould's Mollusca and Shells of the U. S. Explor. Exped., 1852;—under Wilkes). Shell oval, elevated or depressed, the dorsal ridge more or less angular. Valves strong. Surface lusterless, finely sculptured with wavy, crenulated longitudinal riblets, often more or less obsolete. Color generally dull brown, blackish-olive or grayish, but sometimes bright orange, scarlet or vivid green. Median valves hardly beaked, the lateral areas slightly raised, granose, limited by a raised granose riblet. Central areas having close fine longitudinal riblets, with crenulated or latticed interstices, the riblets finer and converging on the ridge of the last 6 valves, diverging on the second valve, or strongly diverging on the ridge of all valves, like a series of superimposed *V*'s. Anterior valves having about 10 narrow radiating granose riblets, the intervals granose. Tail valve depressed with posterior mucro, the posterior slope very short, emarginate behind. Interior bluish-green, stained with lilac on the central callus. Anterior valve having 8, median 1 short slit, the teeth long, deeply striated outside and thickened or propped outside at the sides of the slits. Posterior valve having a rounded sinus behind, with one oblique slit on each side, the plate roughened outside near the slits. Sutural plates broad, the sinus extremely shallow and small. Girdle rather narrow, densely covered with round, curved or curled hairs. Length, 52; breadth, 38 mm. (Tryon Manual Conch.) San Juan Island, Wash., and general.\*—Shumagin Islands, Alaska, to Rosario, Lower California.

*Mopalia muscosa hindsi* Reeve, 1847. (Pl. 12, figs. 67 a-b, Reeve & Sowder's Conch. Iconica, *Chiton*;' also pl. 62, figs. 99-100, Tryon

& Pilsbry's Manual Conch., vol. 14). Shell elongated and much depressed, (the angle of divergence about  $140^{\circ}$ ), the girdle encroaching the sutures. External color a light or dark shade of olive. Surface smoother than in typical *muscosa*; the granose-corrugation being more or less zigzag or criss-cross on the central areas, obliquely corrugated-granose on the lateral areas. Interior white, with short crimson rays under the beaks; tail sinus visible outside. Girdle with few and short hairs. Dimensions about as in the typical. (Tryon Manual Conch.) San Juan Island, Wash., and general.\*—Sitka, Alaska, to Gulf of California.

*Mopalia muscosa laevior* Pilsbry, 1918. The principal mutations of this type of *Mopalia* are (1) toward still smoother forms entirely lacking pitted or reticulated sculpture, having only a few subobsolete longitudinal wrinkles on the ridge, the painting in concentric streaks (following growth marks) on each valve. The *Chiton vespertina* of Gould is closely connected with this form. Size about the same as typical. (Tryon Manual Conch.) Off San Juan Island, Wash., in 25-30 fathoms.\*—Puget Sound.


*Mopalia muscosa kennerlyi* Carpenter, 1864. M. t. "M muscoso" forma, indole, sculpturaque simili; sed multo magis elevata; plus minusve rubente, plus olivaceo variegata, intus palida; granis lateraibus fere aequalibus; liris centralibus haud acutis, interstitiis rarius cancellatis; suturis undatis, apicibus valvarum prominentibus; valva antica octoradiata, radiis granulosis, margine octies inciso; valvis intermediis utraque semel incisis; valva postica mucrone obsoleto, sinu postico alto, angustiore, marginibus anticis valde alatis, lateribus posticis semel incisis. Hab. Insinu Pugetiano; sp. unicum leget Kennerley. Sculpture fainter; olive with red: ridge angular; post. valve waved. (Carpenter). Length 30, breadth 15 mm. Puget Sound.—Shumagin Islands, Alaska, to Monterey, Calif.

*Mopalia imporcata* Carpenter, 1864. (Pl. 62, fig. 98, Tryon & Pilsbry's Manual Conch., vol. 14). Shell small, oblong, strongly elevated and acutely carinated, the side-slopes straight. Buff-white, slightly stained with rust-brown. The median valves are acute at the umbo, but there is no projecting beak; lateral areas bounded by a strongly elevated, narrow, crenulated diagonal rib, and having a wider rib at the sutural margin, also crenulated, thus denticulating the suture; the space between the 2 lateral ribs being finely corrugated-granose. Central areas sculptured with strong, curved longitudinal ribs, which converge forward somewhat, toward the median keel; the

intervals between these ribs being closely and finely latticed across by threads radiating from the beaks. Anterior valve having 8 strong narrow, raised ribs, with one wider rib at each sutural edge. Posterior valve depressed, the mucro situated at the posterior end. Interior white; sinus very small and shallow. Anterior valve having 8, median 1 slit; teeth but little thickened along the slits. Posterior valve having a rather wide moderately deep rounded tail sinus, and a single slit on each side. Girdle leathery, dusty, with a hair-pore at each suture, and some scattered or alternating hairs. Length 10, breadth 6 mm.; divergence 95'. (Tryon Manual Conch.) Puget Sound.—Forrester Island, Alaska, to San Pedro, Calif.

*Mopalia sinuata* Carpenter, 1864. (Pl. 92, figs. 95-97, Tryon & Pilsbry's Manual Conch., vol. 14). Shell oblong, elevated and strongly carinated, the side-slopes straight. Color whitish, clouded with delicate blue-green and maculated with rich tawny brown. Median valves hardly beaked, the lateral areas not raised, but strongly defined by an elevated diagonal rib; sculptured with 2 oblique series of fine riblets forming a latticed pattern. Central areas having a series of longitudinal curved riblets converging toward the median keel, crossed by curved radiating threads a little finer and less prominent. Anterior valve having 8 (not counting the posterior sutural borders) strong radiating ribs narrower than the latticed intervals. Posterior valve depressed, the mucro being at the posterior third. Interior bluish-white. Sinus very small and narrow. Anterior valve having 8 slits, median 1 slit; teeth thickened outside at the edges of the slits. Posterior valve having a deep rounded median sinus behind (which is continued upward in a superficial excavation to the mucro), and a single slit on each side. Girdle rather narrow, leathery, "dusty," bearing a few hairs, with a rounded pore at each suture. Length 11.5; breadth 7 mm.; divergence 105'. Pea Vine Pass, San Juan County, Wash.\*—Forrester Island, Alaska, to San Francisco, Calif.

*Mopalia goniura* Dall, 1919. Chiton of small size with a high arched back, of a yellowish color flecked with scarlet; the girdle red, velvety, with numerous sparsely scattered large brown spines (broken off in the type, chiefly near the inner border, and smaller ones scattered near the outer part; gill rows about two-thirds the length of the foot; anterior valve with 8 slits, posterior with 4, intermediate valves with single slits; anterior valve with 10 radii, the 2 marginal wider, otherwise the surface is covered with punctate reticulation; posterior valve small, the mucro at the posterior third, sculpture of the posterior tract in radial lines of pustules, the central area has very similar

ornamentation; the posterior sinus is narrow -shaped, the apex reaching the mucro, the anterior sinus also narrow and acute, the sutural laminae broad; jugal and pleural areas of the intermediate valves not separated, the sculpture of oblique reticulation with emphatically punctate interstices; lateral areas similarly sculptured, bounded on each side by a slender rib, internally whitish with a narrow notch-like sinus. Length, 12; width, 6; height, 4 mm. (Dall). Turn Island, Wash., in 6 fathoms.\*—Granite Cove, Port Althorp, Alaska, to Puget Sound.

#### PLACIPHORELLA Carpenter, 1878

Valves very broad and short, the middle ones much broader than those toward the ends; head valve narrowly crescentic, tail valve still smaller, with posterior mucro. Sinus small; insertion-plates short and thick, teeth lobed or rugose. Slits 8 or more in the anterior, 1 in the median, 2 in the posterior valve, which has also a shallow posterior sinus. Eaves spongy. Girdle widest, often very wide, in front, bearing sparsely scattered, scaled hairs. Type *P. velata* Carpenter.

*Placiphorella velata* Carpenter, 1878. (Pl. 2, fig. 36, Proc. U. S. Nat. Mus., vol. 1; also pl. 66, figs. 6-12, Tryon & Pilsbry's Manual Conch., vol. 14). Shell roundly oval, broad, rather depressed, quite obtusely angled. Surface lusterless. Light colored along the middle, mainly olivaceous on the sides, especially the lateral areas; the central areas variously streaked longitudinally with buff, blue, chestnut and pink. Median valves not beaked, marked by growth lines; the lateral areas somewhat raised, having a rounded wide diagonal rib and another at the sutural margin, the space between them more or less excavated. Central areas having a "false beak" or narrow projection forward at the dorsal ridge (only visible when the valves are separated). Anterior valve crescent shaped, sculptured with light concentric growth-lines only. Posterior valve small, slightly waved inward behind, the mucro far backwards, recurved and elevated, the slope in front of it concave in profile, unless the mucro is eroded. Interior white, slightly blue tinted. Sinus in valves i-vi represented by a very shallow wave, the sutural plates continuous, being connected by a plate which fills the sinus like a key-stone; in valves vii-viii the sinus is deeper and more distinctly angular. Anterior valve having 8 slits, the teeth obtuse, short, often bilobed or conspicuously rugose. central valves having 1 slit, teeth wedge-shaped, thicker at the edges of the slit. Posterior valve having a very heavy callus supporting



the short, rugose insertion-plate, which is interrupted posteriorly by a broad, shallow sinus, and has one slit on each side (occasionally 2 on one side). Girdle very broad in front, reddish, fading to yellow toward the outer edge, irregularly and sparsely beset with hairs, of which 1 or 2 are generally to be seen in each suture; a close fringe of short (broken) hairs adorns the girdle-edge. Length 50, breadth 38 mm; divergence 135'. (Tryon Manual Conch.) Sooke Harbor, Vancouver Island.—Vancouver Island to Todos Santos Bay, Lower California.

### Family ACANTHOCHITONIDÆ

KATHERINA Gray, 1847

Valves two-thirds covered by the expanded girdle, the exposed portion divided into dorsal and side areas, instead of central and lateral. Insertion plates sharp, extremely long, thrown forward; that of the head valve with 7-8 slits; sinus deep, spongy. Tail valve with wide caudal emargination or sinus, and several slits, often partly obsolete, on each side. Girdle broad, smooth, poreless, leathery. Gills extending the whole length of the foot. The poreless girdle, the long (ambient) gills, and the abnormally large number and irregularly placed slits of the head valve, all separate this well-founded genus from related groups. The irregularly placed anterior slits it shares with *Amicula* and *Cryptochiton*. There is but 1 species known. (Tryon Manual Conch.) Type *K. tunicata* Wood.

*Katherina tunicata* Wood, 1815. (Pl. 2, fig. 1, Wood's General Conch.; also pl. 1, figs. 1-11, Tryon & Pilsbry's Manual Conch., vol. 15). Shell oblong, elevated, the valves mainly covered by the black, leathery girdle, a small cordate or flask-shaped area of a dark brown color, remaining exposed. The exposed portion is about one-third the entire width of the valve; it is broad behind, and often hollowed out by erosion; narrowing in front like the neck of a flask. The surface when not eroded shows a distinct, smooth and shining dorsal band, the sides (which are not divided into pleuro and lateral areas) being microscopically densely punctate. Anterior valve densely punctate and having a few feeble radii. Posterior valve small. Interior white. Sutural plates enormously produced; the sinus very deep, squared and notched at the sides, exposing a projecting lobe of the extremely porous outer layer. Anterior valve having 7 or 8, central 1 slit, the insertion-plates extremely long, grooved outside from the short slits to the eaves. Posterior border of the black teg-

mentum broadly reflexed inward. Posterior valve elevated, vertical behind, with a broad median notch or sinus and a variable number (1-4) of small slits on each side. Girdle leathery, smooth, black. Length, 60-70; breadth, 32-40 mm. (Tryon Manual Conch.) San Juan Island, Wash., general on all the islands.\*—Bering Sea, Alaska, to Catalina Island, Calif.

### Family CRYPTOCHITONIDAE

CRYPTOCHITON Gray, 1847

Valves entirely concealed in the leathery girdle, and lacking tegmentum; their posterior margins produced backward in a deep lobe on each side, the lobes united across the median line, causing the apices of all valves to be removed inward from the posterior edge. Slits subobsolete or lacking in the intermediate valves. Girdle covered with minute tufts of short bristles. Gills extending the entire length of the foot. (Tryon Manual Conch.) Type *C. stelleri* Middendorff.

*Cryptochiton stelleri*, Middendorff, 1846. (Pls. 1-9, Middendorff's *Beitrage zu einer Malacologia Rossica*, vol. 1). Oblong, rather depressed, the bilobed posterior outlines of the valves (in dry specimens) showing through the leathery integument, which completely covers the valves. Color a dull ferruginous or brick-red, very well preserved specimens being rendered much brighter by the closely placed fascicles of brilliant vermillion spines. The valves are wholly concealed, white or flesh-colored, entirely lacking the outer colored layer (tegmentum) of other Chitons; their edges are more or less thinned and crenulated by radial striae. Anterior valve having the apex at the posterior third, and with 4-7 slits. Intermediate valves having the apex near the posterior third; formed of 2 large anterior lobes expanded at the sides, and 2 smaller, narrow posterior lobes. Posterior valve having the mucro posterior or near the posterior third; deeply sinused in the rear, and usually having a slit on each side of the sinus. Girdle leathery, thick, red, densely covered with countless minute fascicles of vermillion spinelets. Length 15-20 cm. (Tryon Manual Conch.) Off San Juan Island, Wash., and general.\*—Bering Sea to San Nicholas Islands, Calif., and Hakodate, Japan.

## Brachiopoda

### Family RHYNCHONELLIDAE

HEMITHYRIS Orbigny, 1847

Shell trigonal, acutely beaked, usually plaited; dorsal valve elevated in front, depressed at the sides; ventral valve flattened, or hollowed along the centre, hinge-plates supporting 2 slender curved lamellae; dental plates diverging. The foramen is at first only an angular notch in the hinge-line of the ventral valve, but the growth of the deltidium usually renders it complete in the adult. (Woodward). Type *Rhynchonella psittacea* Gmelin.

*Hemithyris psittacea* Gmelin, 1792. (Plate 29, figs. 8-12). Shell somewhat triangular, globose, broadest anteriorly, tapering posteriorly, lateral margins rounded. Dorsal valve inflated, especially at the umbo, more or less divided into 3 lobes, of which the central one forms a mesial fold, scarcely defined in some specimens, much more so in others; front line nearly straight or 3-lobed. Ventral valve much less convex than the dorsal one, rather flattened, with a broad, channeled, flattened, longitudinal mesial sinus; beaks sharply pointed, incurved, under which is situated an incomplete elongated foramen, margined anteriorly by the umbo, and laterally by triangular deltoidal plates; beak-ridges not sharply defined; lateral margins of the valve sinuous, curved in front. Surface of valves radiately and finely striated. Shell-structure fibrous. Valves strongly articulated by curved teeth in the ventral valve, fitting into sockets in the dorsal one. Hinge-plate in the dorsal valve deeply divided, supporting two short, flattened, grooved and curved lamellae. At the bottom of the dorsal valve are seen the quadruple muscular impressions left by the adductor or occlusor muscles, each pair being separated by a short medio-longitudinal ridge. In the interior of the ventral valve the teeth are supported by dental plates extending to the bottom of the valve, and at their base a semi-circular ridge on either side encloses a saucer-shaped depression in which are situated the muscular scars. Close under the beak the peduncular muscles leave a small scar; lower down and toward the centre of the valve is situated a divided heart-shaped scar due to the adductor or occlusor muscles; and on each side of these are situated, one above the other, the divaricator and ventral adjustor muscular impressions. Length 1 inch three lines, width 1 inch one line, depth 9 lines. (Davidson Recent Brach.) Off

Lopez Island, Wash., in 25-35 fathoms.—Seahorse Island, Arctic Ocean, to Astoria, Ore.; Atlantic.

### Family TEREBRATULIDAE

#### TEREBRATULINA Orbigny

Shell finely striated, auriculate, deltidium usually rudimental; foramen incomplete; loop short, rendered annular in the adult by the union of the oral processes. Type *T. caput-serpentis* Linne.

*Terebratulina unguicula* Carpenter 1865. (Plate 27, figs. 2-5). Shell ovate, longer than wide; valves almost equally convex, rounded laterally and in front; lateral sides of the umbo strongly auricular, especially in young and middle-aged specimens. Ventral valve evenly convex, but sometimes slightly depressed anteriorly; beaks short, obliquely truncated by a rather large incomplete foramen, margined anteriorly by the umbo of the dorsal valve and by 2 small lateral deltidia. Surface of valves marked by numerous delicate riblets, simple and stronger at their origin, but rapidly augmenting in number from bifurcation and by the interpolation of shorter riblets between the longer ones. Valves crossed with concentric raised striae. Loop short and simple, the crura disunited in the young, annelliform in more advanced age. Color light yellowish white. Length, 13; breadth, 10; depth, 5 lines. (Davidson Recent Brach.) Off Lopez Island, Wash., and general in 25-60 fathoms.\*—Pribilof Islands, Alaska, to Cape San Lucas, Lower California.

*Terebratulina kiiensis* Dall & Pilsbry, 1891. (Plate 29, figs. 13, 14). This shell differs from the largest *T. unguicula* Cpr. with which we have been able to compare it in the following particulars. It is larger and proportionately somewhat wider and the beak proportionately shorter, much such differences as would come about by increased size in such a species as *unguicula*. If more material should prove that the supposed variety cannot be connected with *unguicula*, the varietal name can be taken as specific. Total length, 44; length of the heamel valve, 35.5; maximum width, 40; maximum diameter, 21.5 mm. (Dall & Pilsbry). Departure Bay, Vancouver Island, plentiful; by Rev. G. W. Taylor.\*—Unalaska, Alaska, to San Nicolas Islands, Calif.; Japan.

### Family TEREBRATELLIDAE

#### TEREBRATALIA Beecher, 1873

Shell smooth or radially plaited; dorsal valve longitudinally impressed; hinge-line straight or not much curved; beaks with a flat-

tened area on each side of the deltidium; foramen large; deltidium incomplete; loop attached to the septum. (Arnold). Type *T. transversa* Sowerby.

*Terebratalia transversa* Sowerby, 1846. (Plate 29, figs. 1-3). Shell transversely ovate, flexuously contorted, concavely impressed in the middle, dull yellowish-white, beaks rather short, concavely flattened beneath on each side, truncated, foramen very large, deltidium small, widely divided; valves smooth, wrinkled with lines of growth toward the margin. (Sowerby). Length 42, height 37 mm. Puget Sound, in 25-35 fathoms.\*—Alaska to San Pedro, Calif.

*Terebratalia transversa caurina* Gould, 1850. (Plate 29, figs. 4-7). Shell small, dusky ash-color, moderately convex, rather broader than long; ventral margin rounded, with a central broad flexure, and corresponding depression in the smaller, and angulation of the larger valve; surface with 12 or more obtusely angular, radiating ribs, gradually enlarging, and sometimes bifurcating; interspaces and elevations about equal; the whole with microscopic opaque dots; small valve having the apex a little pointed, and the posterior outlines otherwise rectilinear, and forming a very obtuse angle; large valve forming about a right angle at beak, but with the lateral outline concave, and the margin incumbent, forming a broad nearly flat area; beak but little raised, pointed; the ligament aperture very large, circular, a part of its margin formed by the apex of the small valve; internal apophysis similar to that of *T. pulvinata*, but much more delicate and threadlike, the 2 branches curving toward each other so as almost to touch. Length half an inch; breadth eleven-twentieths of an inch. (Gould). Off San Juan Island, Wash., in 25-35 fathoms.\*—Bering Sea to San Diego, Calif.

LAQUEUS Dall, 1870

Shell with the reflected portion of the loop attached by slender processes, on each side, to the haemal processes, at or near the points where the 2 septal processes branch off to the septum. Foramen complete. It will be observed that the reflected part of the loop is attached by the 2 (lateral) processes, not to the septum nor to the septal processes, but to the haemal portions of the loop, (which I have termed haemal processes); thus the 2 septal processes, the 2 lateral processes, and the "bight" of the neural loop, form a somewhat sinuous ring, intersected by the point of the septum, the haemal processes and the 2 sides of the neural loop. (Dall). Type *L. californicus* Koch.

*Laqueus californicus* Koch, 1848. (Plate 28, figs. 1-4). Shell large, longitudinally oval, inflated; margins slightly sinuous. Dorsal valve uniformly convex, with occasionally a very slight tendency to depression close to the frontal margin. Ventral valve a little deeper than the dorsal one, with sometimes a slight indication of a mesial longitudinal elevation or flattened fold; beaks curved, truncated by a small circular foramen, margined anteriorly by two wide deltidial plates; beak-ridges sharply defined, leaving between them and the hinge-line a flattened space. Surface of valves smooth, with concentric lines of growth, shell-perforations rather large. Color livid yellowish brown or light reddish brown. In the interior of the dorsal valve the hinge-plate is bifid; cardinal process inconspicuous. The septum, of small elevation, extends from under the middle of the hinge-plate to a little more than a third of the length of the shell; the principal lamellae of the loop, after having been attached to the angles of the hinge-plate and giving off short curved crura, proceed a short distance, when they again give off 2 slightly oblique laminae, which become attached to the anterior edge of the mesial septum. The principal stems of the loop then extend to within a short distance of the frontal margin, where they become deflected in the shape of a horseshoe, giving off on each side a short lamella near their upper extremity, thus connecting the reflected portion with the principal stems of the loop close to the point where the 2 oblique lamellae leave for their attachment to the mesial septum. (Davidson Recent Brach.) Off Vancouver Island.—B. C. to Point Loma, Calif.

*Laqueus californicus jeffreysi* Dall, 1873. Shell magasellioid in external appearance, smooth, with an incomplete horseshoe-shaped foramen. Without a septum in either valve. Loop unattached, except by the haemal processes to the hinge plate. Loop complex, somewhat like that of *Ismenia sanguinea*. Crura well marked, long and slender in the adult. Haemal processes connected, the connecting band produced into a sharp point in the median line with a sinus above it; the point produced toward the haemal valve, below the haemal process. Lateral loops open. Anterior extremities of the haemal processes produced into sharp points. Reflected portion of the loop broad, connected by perpendicular lamellae to the haemal band between the haemal processes, and by lateral extensions to the haemal processes themselves. Shell smooth, waxen, with close conspicuous punctations; subcircular compressed, with the margin of the valves nearly straight. Area marked by an incised line, deltidia wanting; the two separated parts of the area narrow, and very small. Beak of the

haemal valve rather prominent, smooth. Neutral beak incurved, truncated, not prominent. (Dall). Departure Bay, Vancouver Island.—B. C.; northeastern Atlantic.

*Laqueus californicus vancouverensis* Davidson, 1887. (Plate. 28, figs. 5-10). Off Vancouver Island we find in large numbers a smaller race or northern form which Mr. Dall considers to be *Laqueus californicus*. This shell has also been quoted by Mr. J. F. Whiteaves from off Metla-katla, Queen Charlotte Islands and from between Race Island lighthouse and Victoria harbor, in from 30-70 fathoms, as well as off the N. W. end of Texada Island, in 40-70 fathoms, west coast of North America. I have examined a number of specimens of this shell, some quite circular, others ovate and truncated anteriorly with a slight depression on the anterior third of the length of both valves. The foramen is also comparatively larger in typical Californian examples of *Laqueus californicus*. Interiorly the loop and its attachments are similar to those of the Californian shell. It is decidedly of a livid yellowish-brown color. After consulting with Mr. Dall upon the subject, he wrote me back, on the 17th. of December 1884: "The shells from Vancouver which I referred to *Laqueus californicus* are, I am quite confident, a northern form of that species, less brightly coloured, thicker, and ruddier. I have northern specimens fully as large as the southern ones, and I believe my *Megerlia jeffreysi* to be the young stage of it. The northern form might perhaps have a varietal name; but if we had plenty of specimens, I think they would be found to intergrade." (Davidson Recent Brach.) Off Lopez Island, Wash., in 25-35 fathoms; rare.\*—Alaska Peninsula to Puget Sound. and the coast of Washington.

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Photograph by Crandall, Palo Alto.



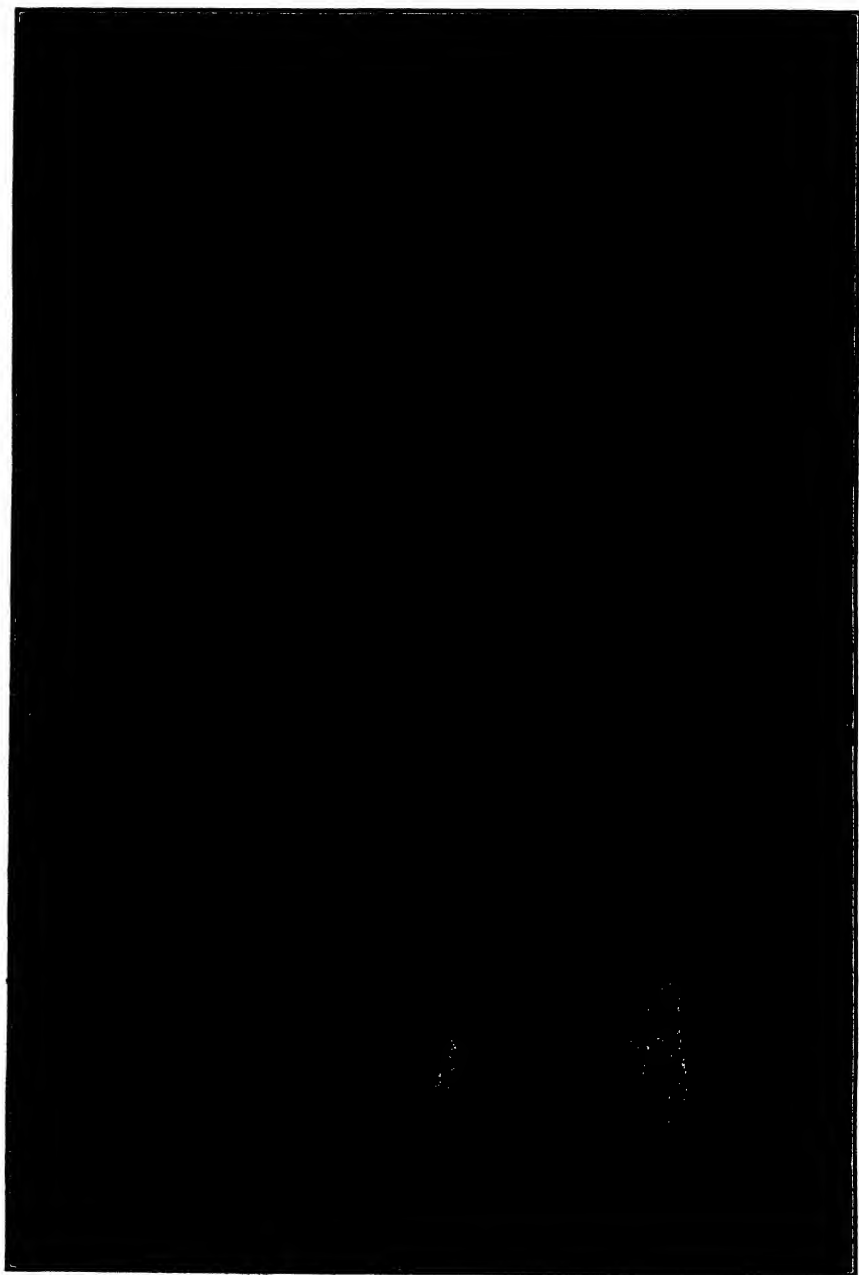


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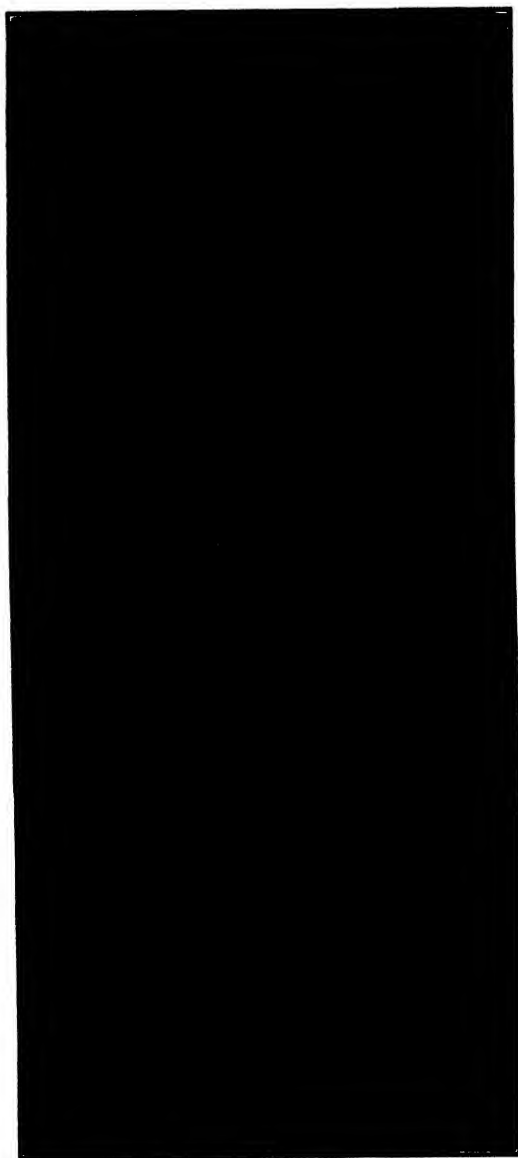


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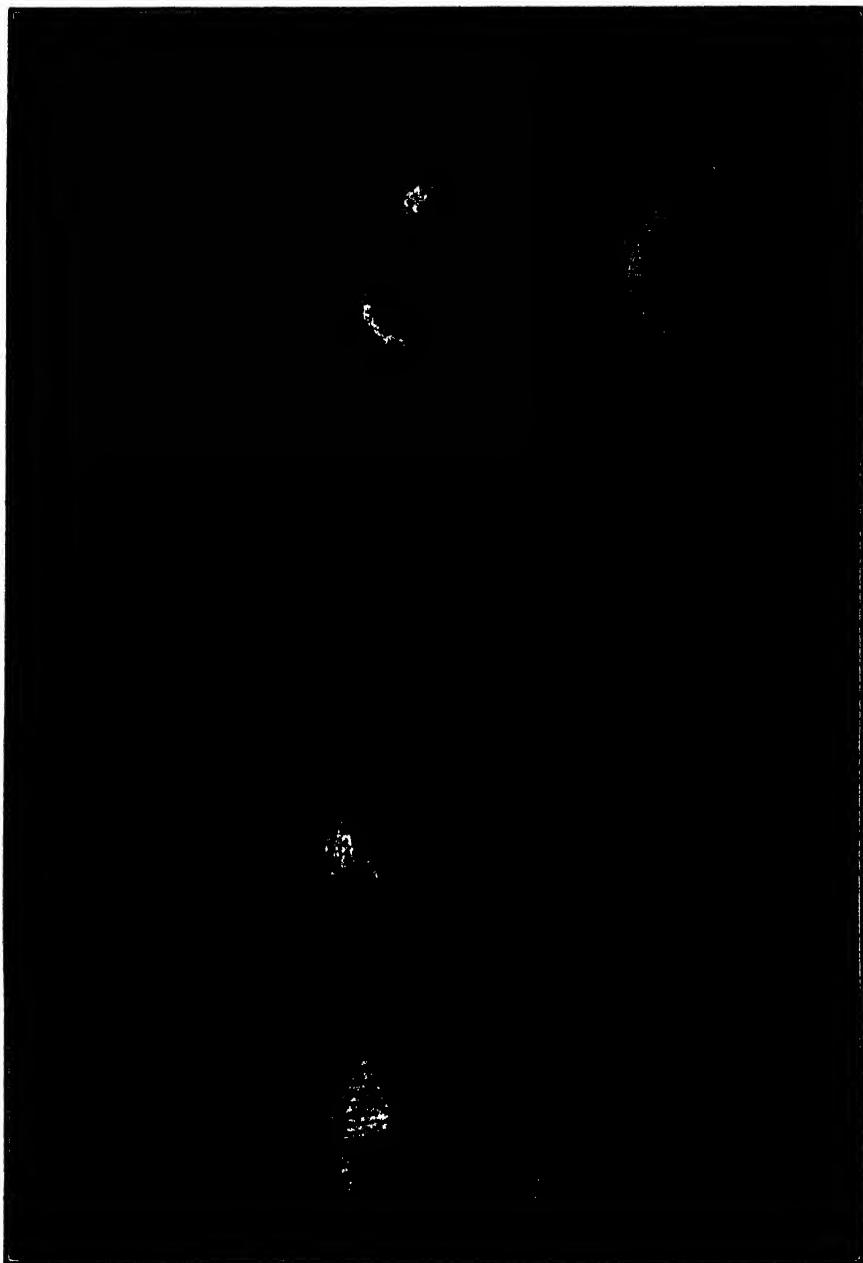


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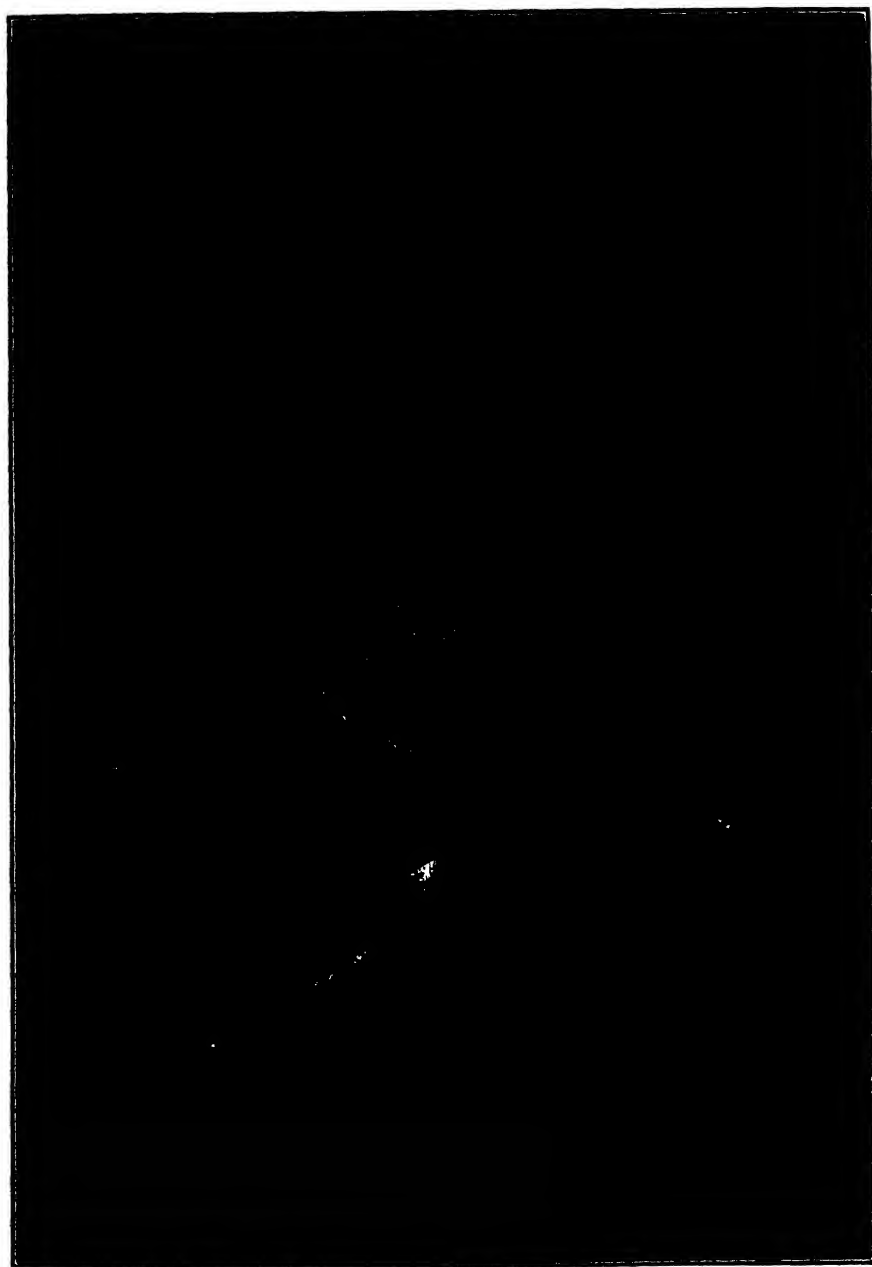


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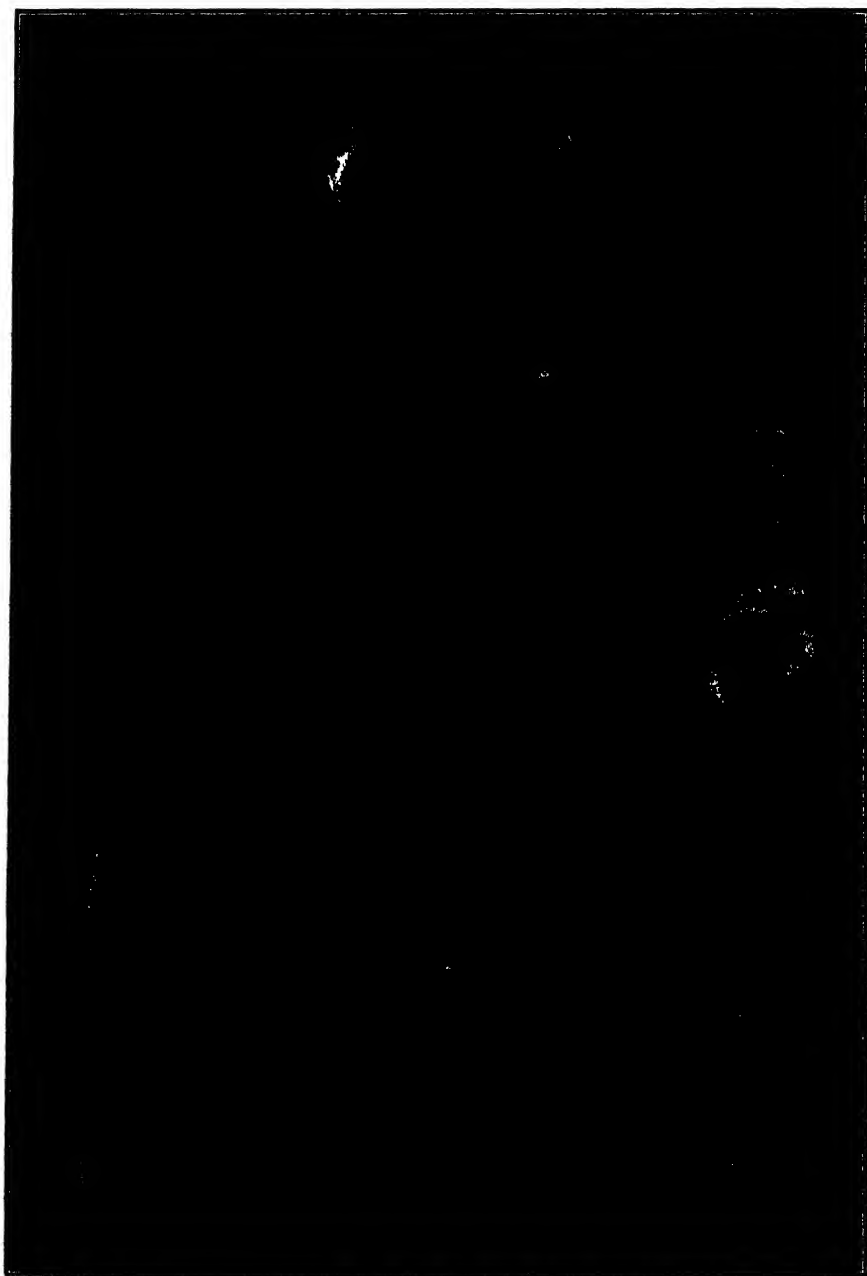


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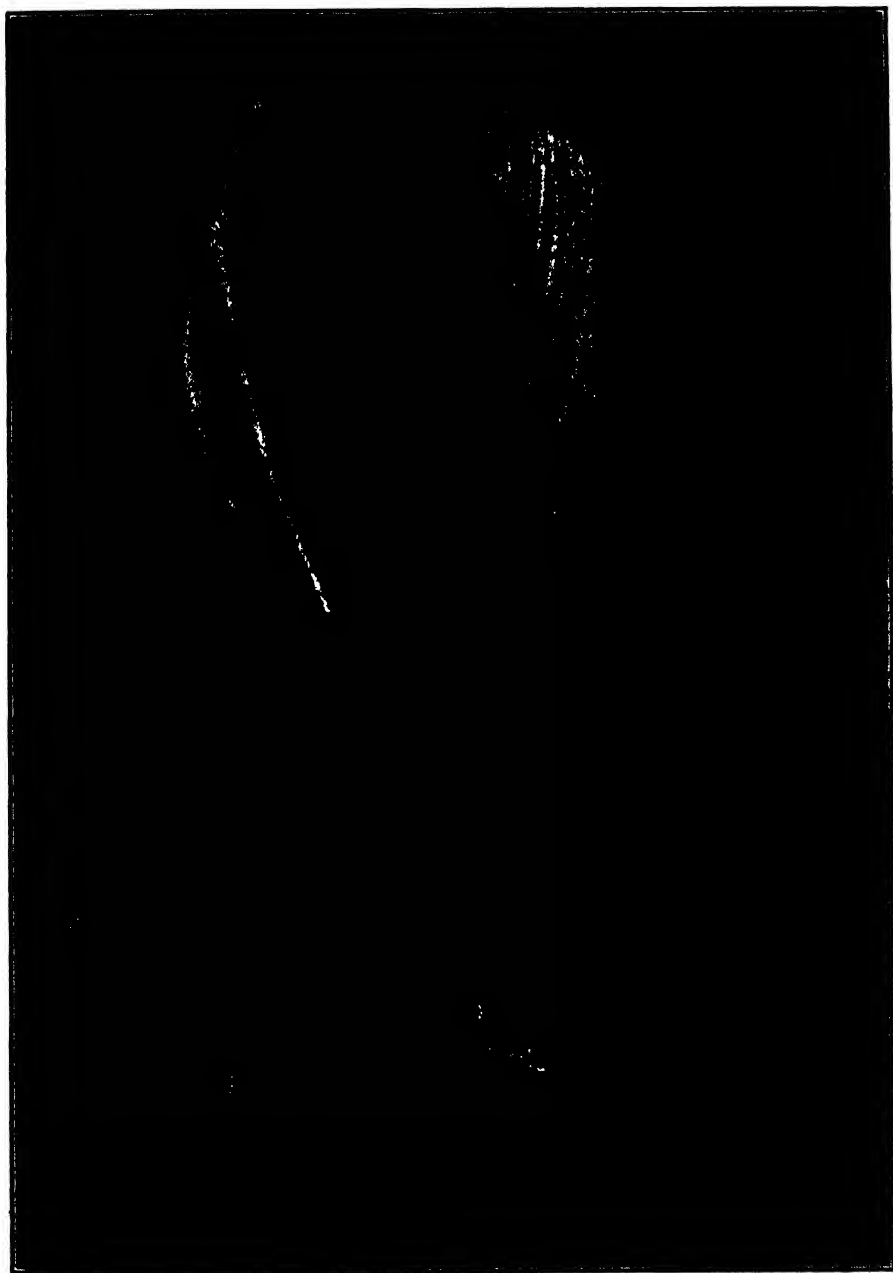


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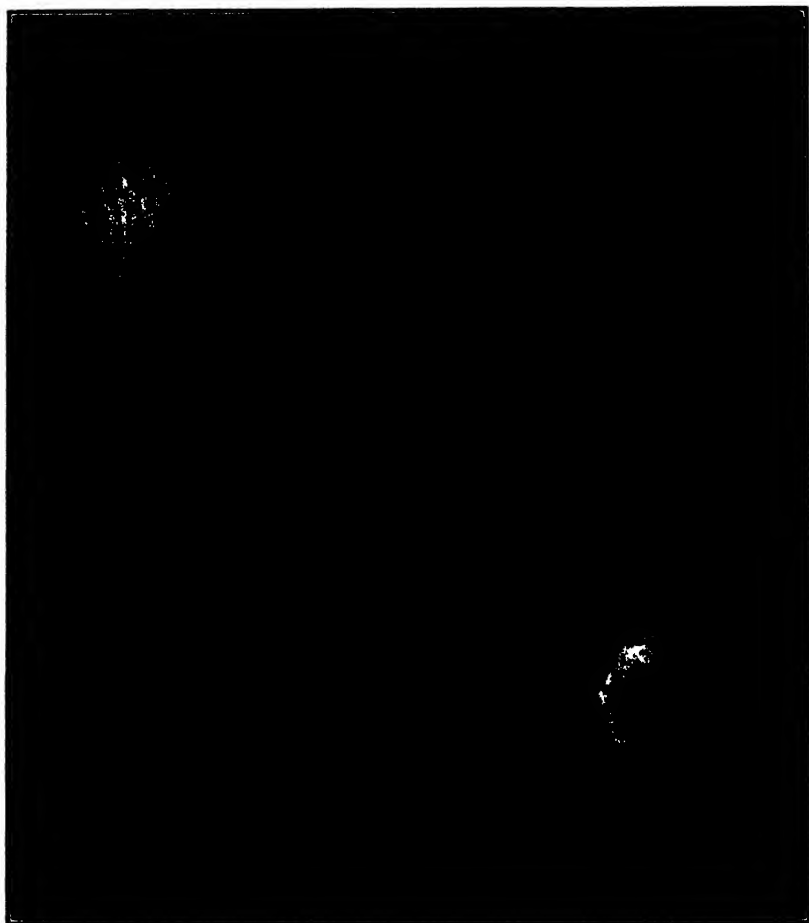


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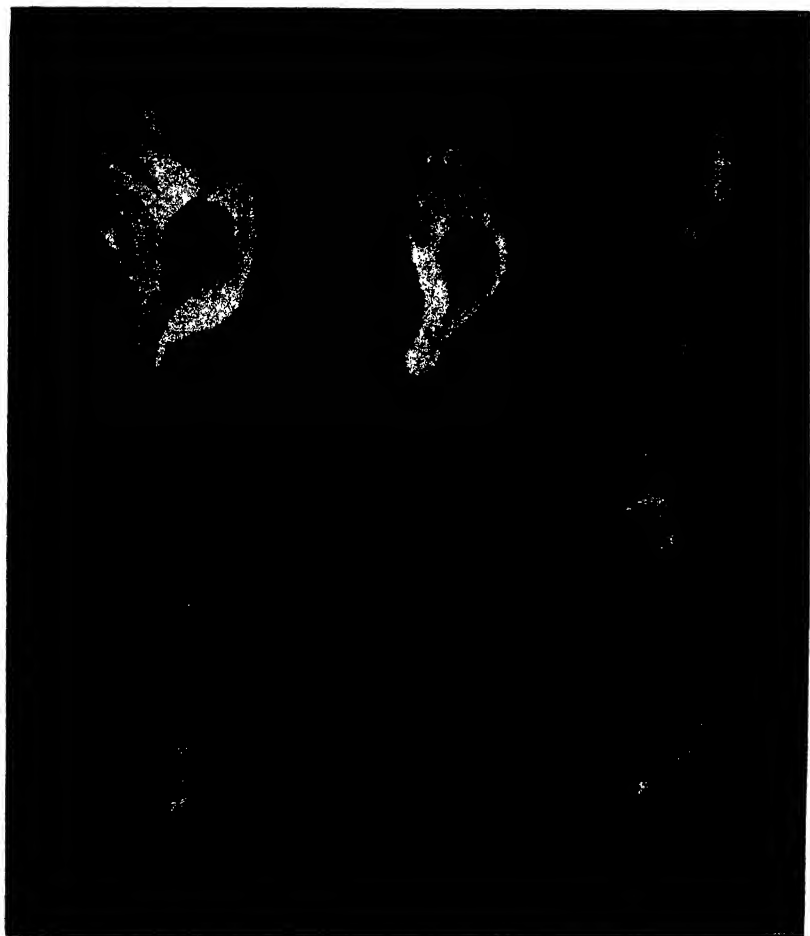


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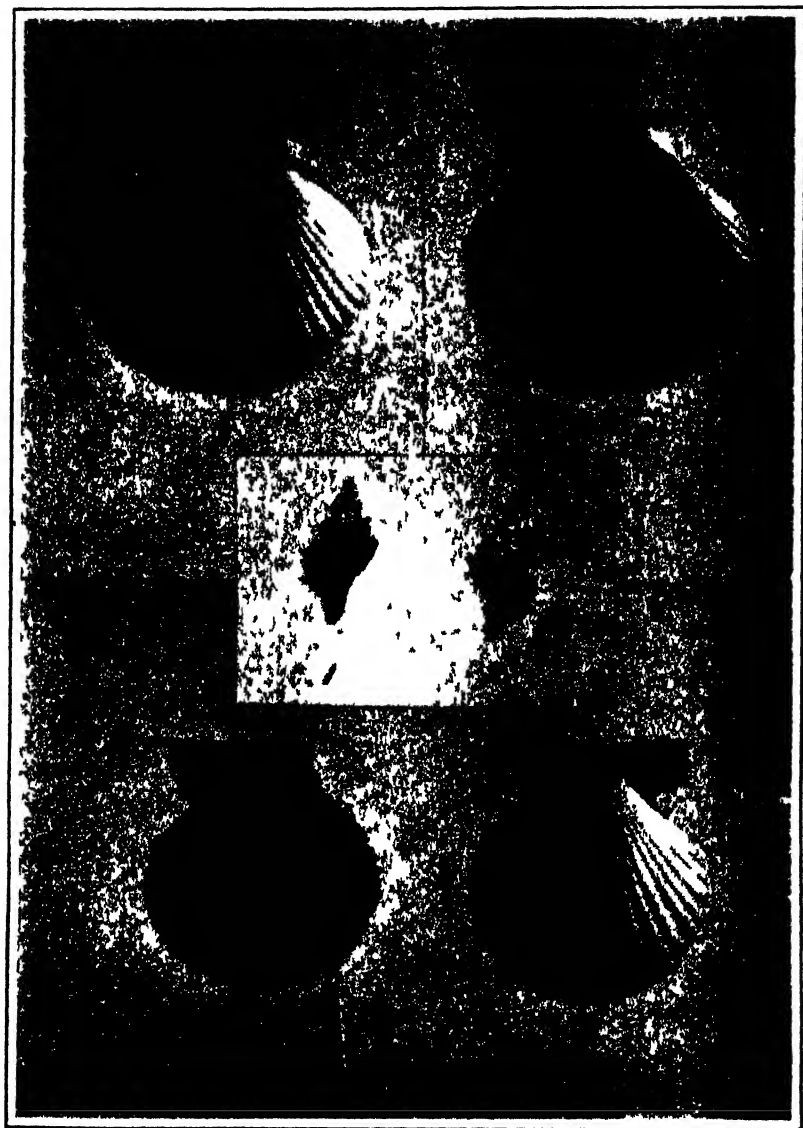


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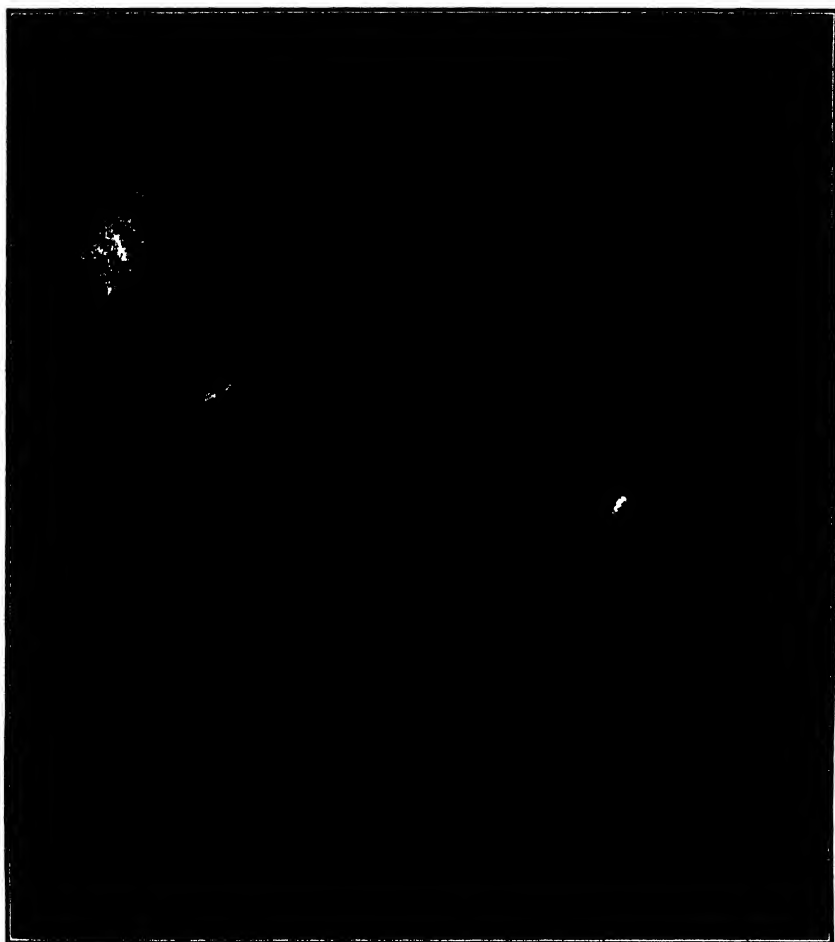


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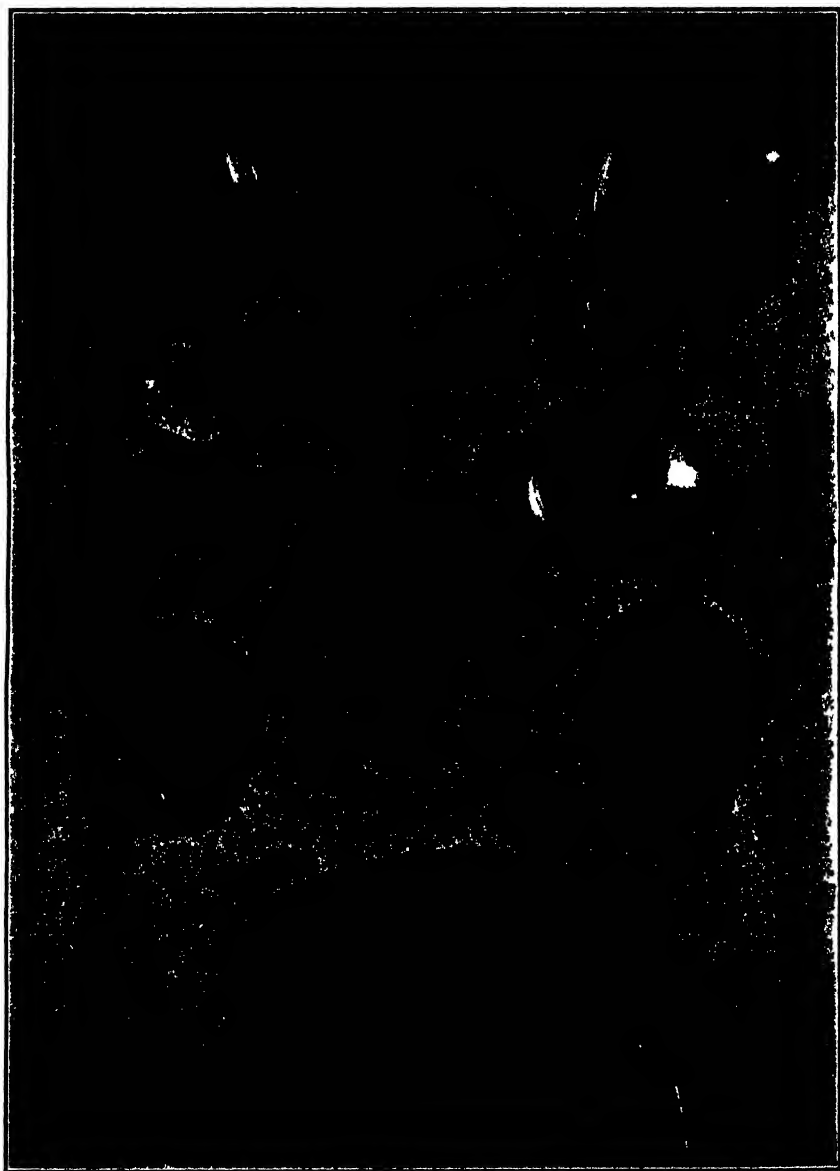


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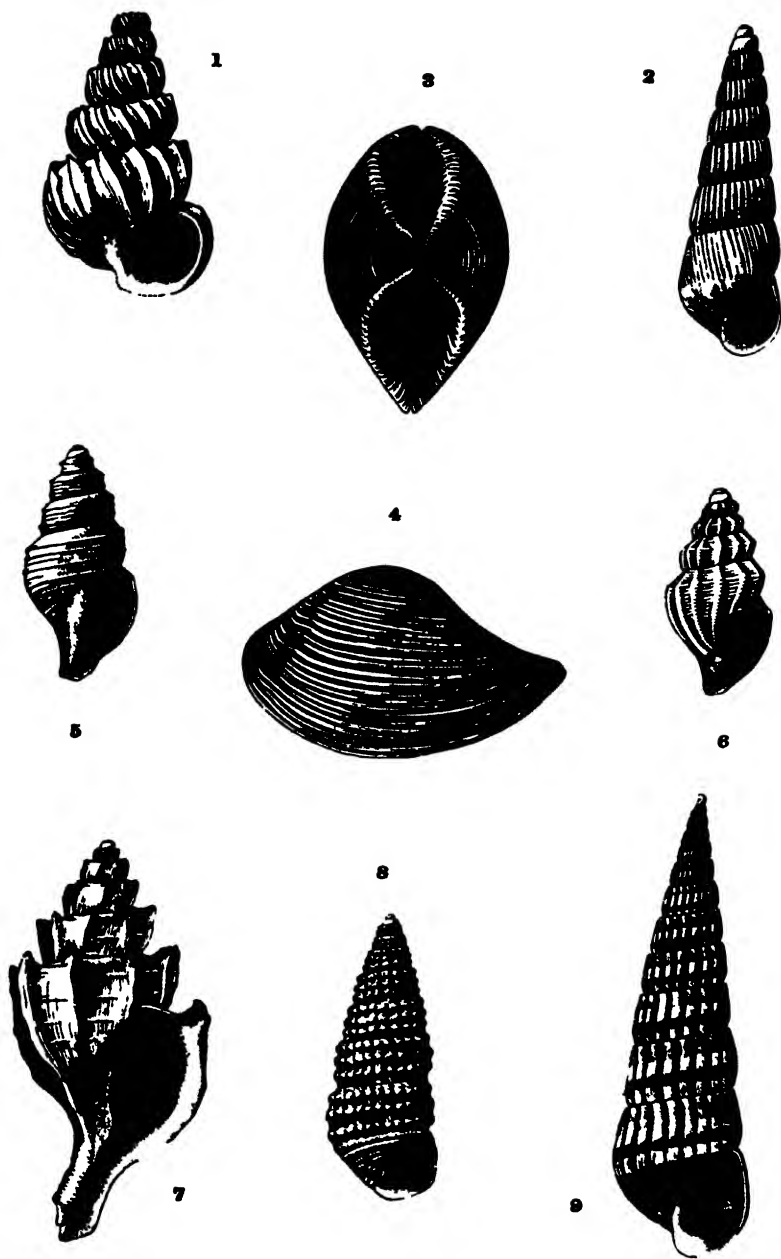
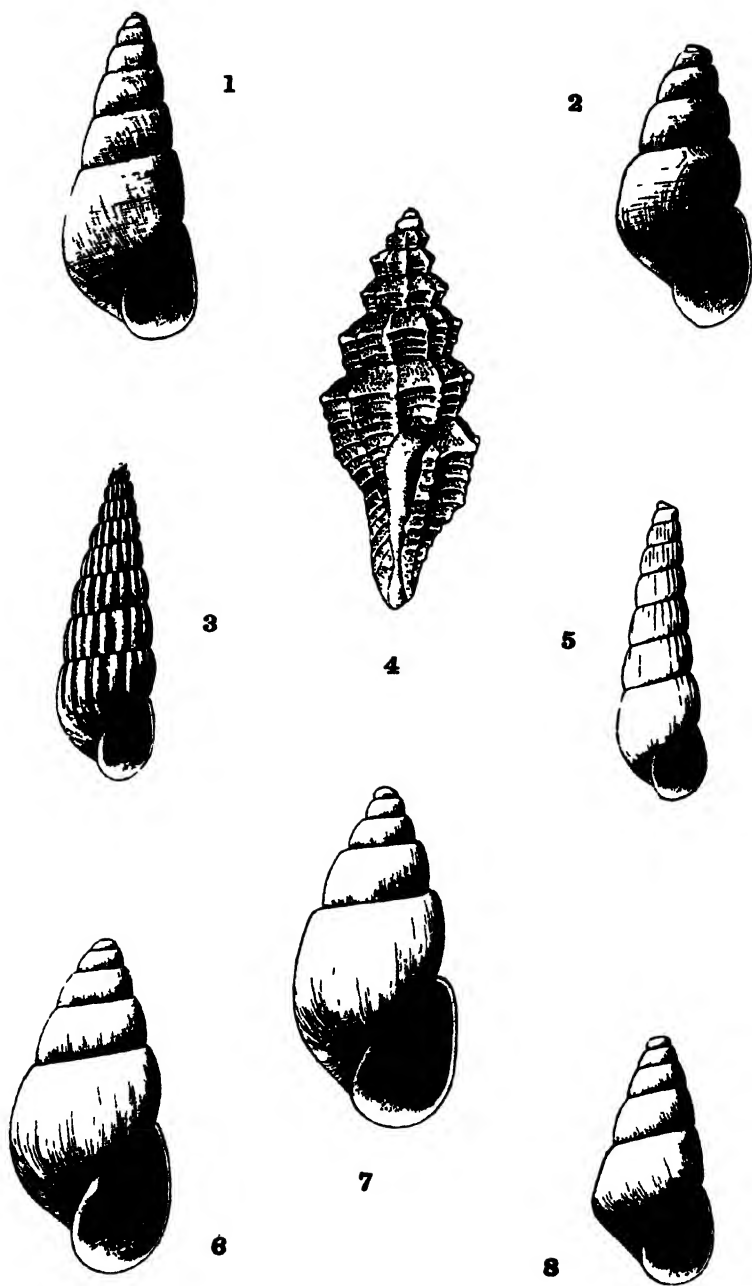


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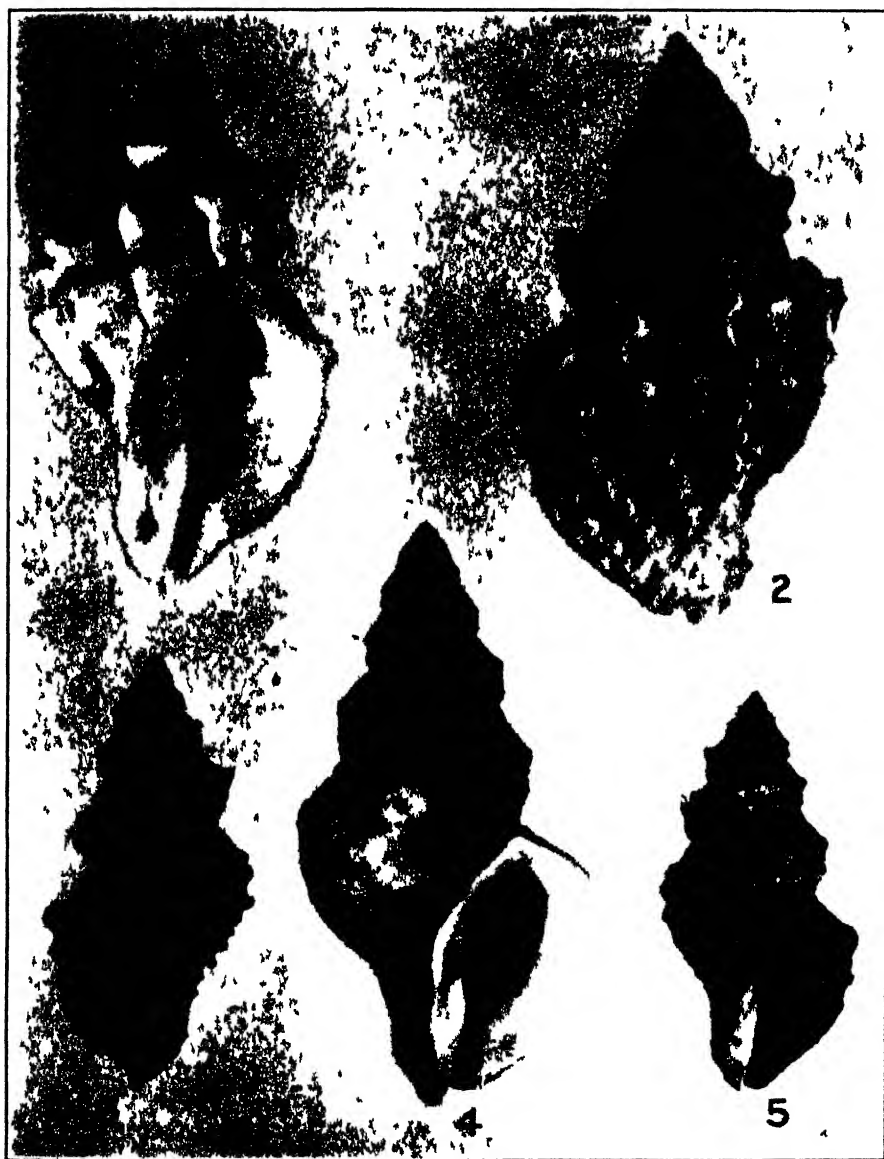


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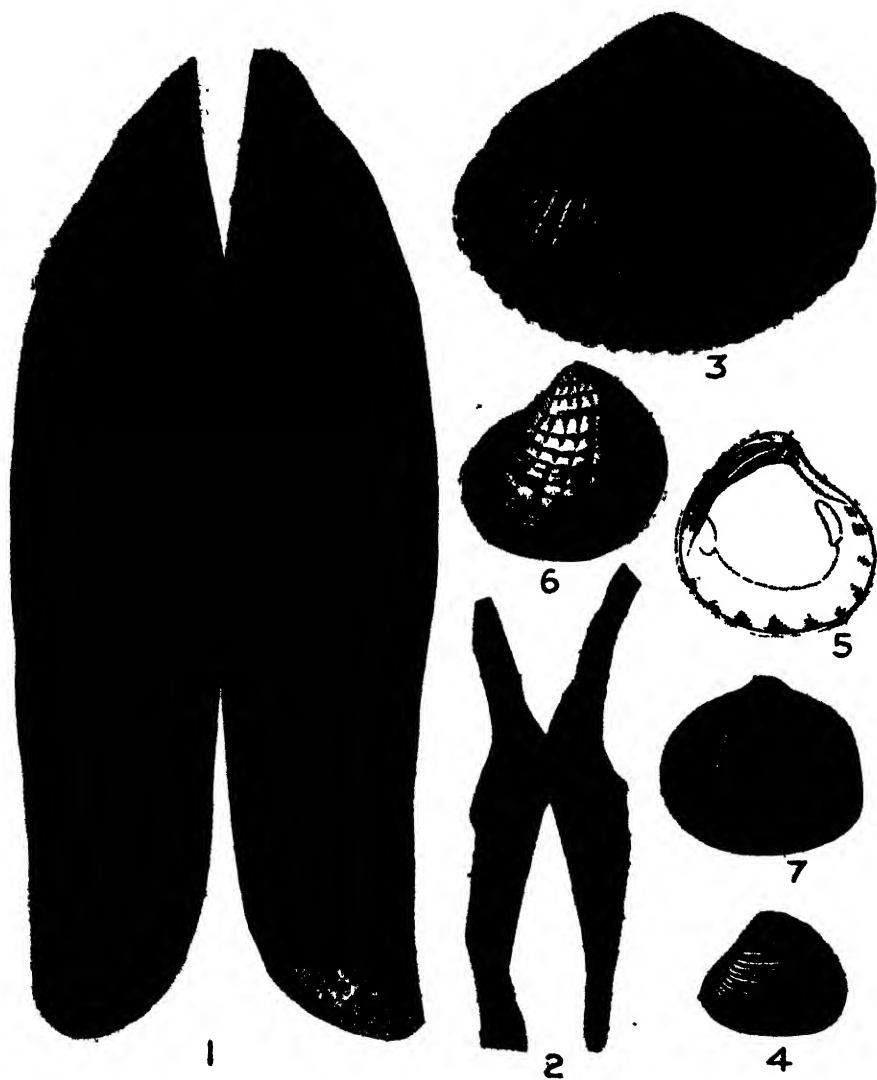


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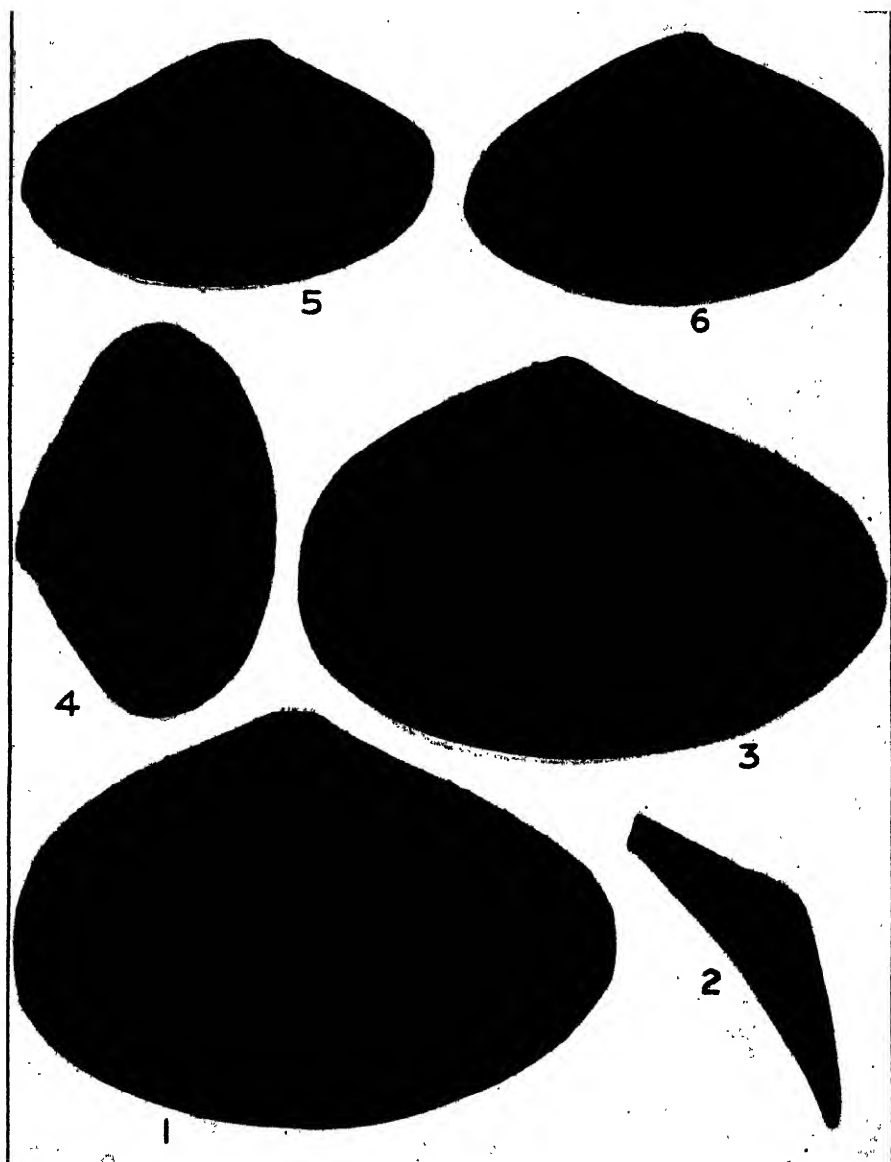


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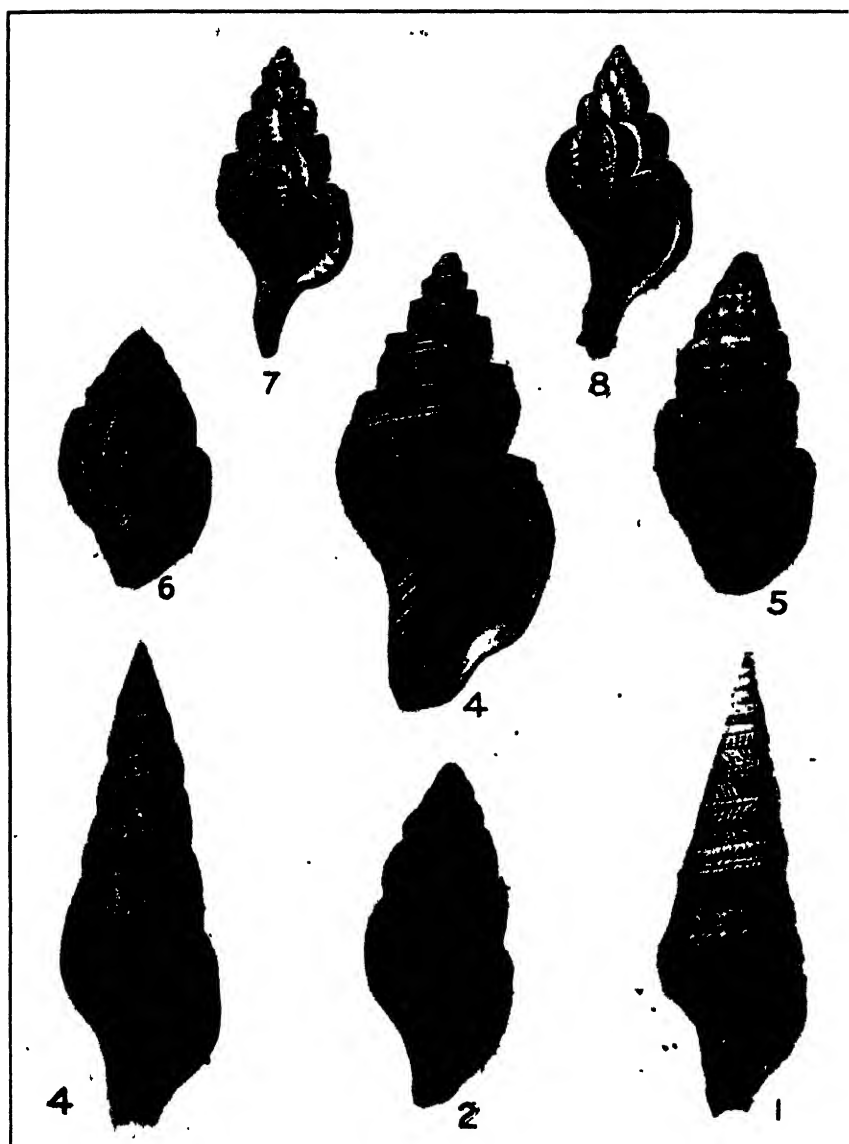


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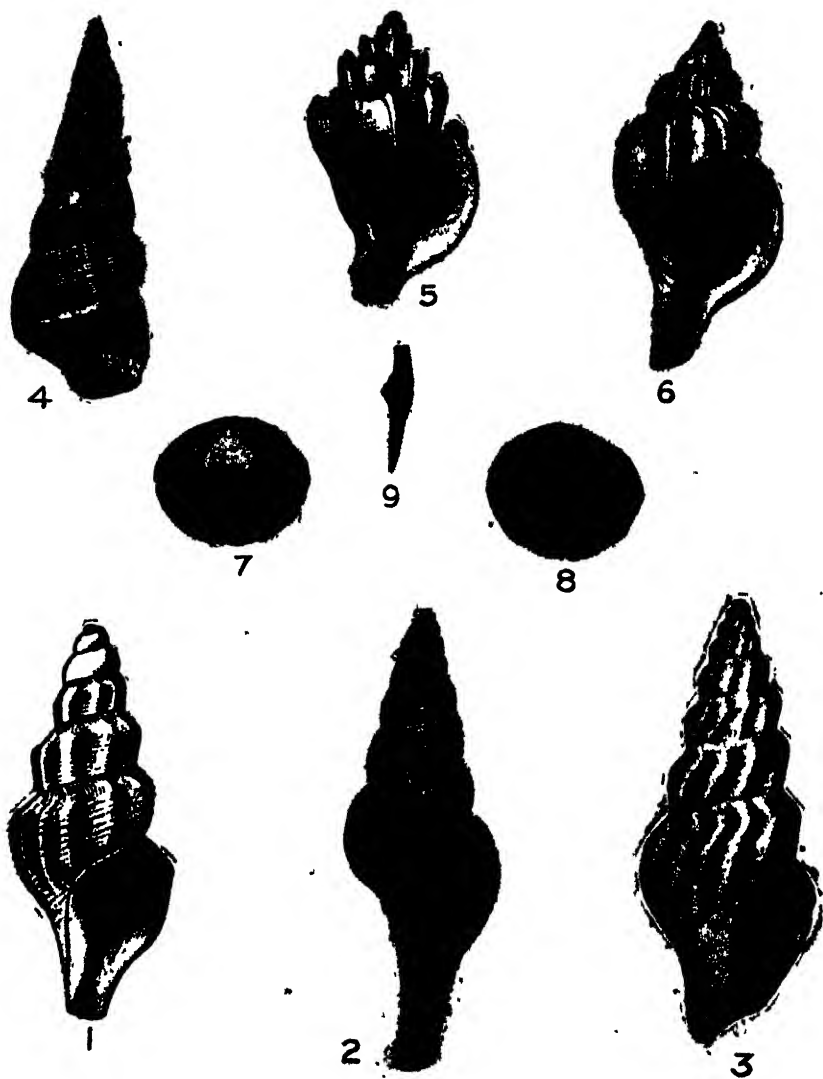


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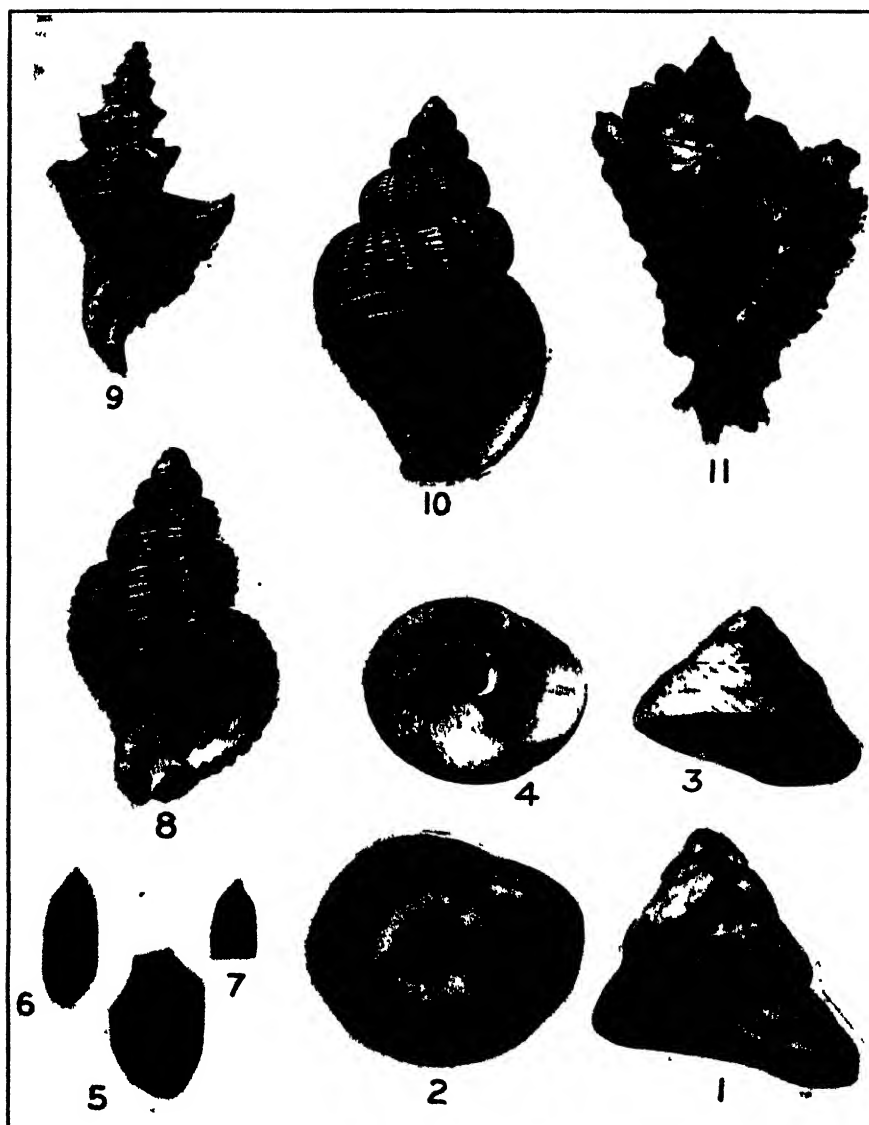


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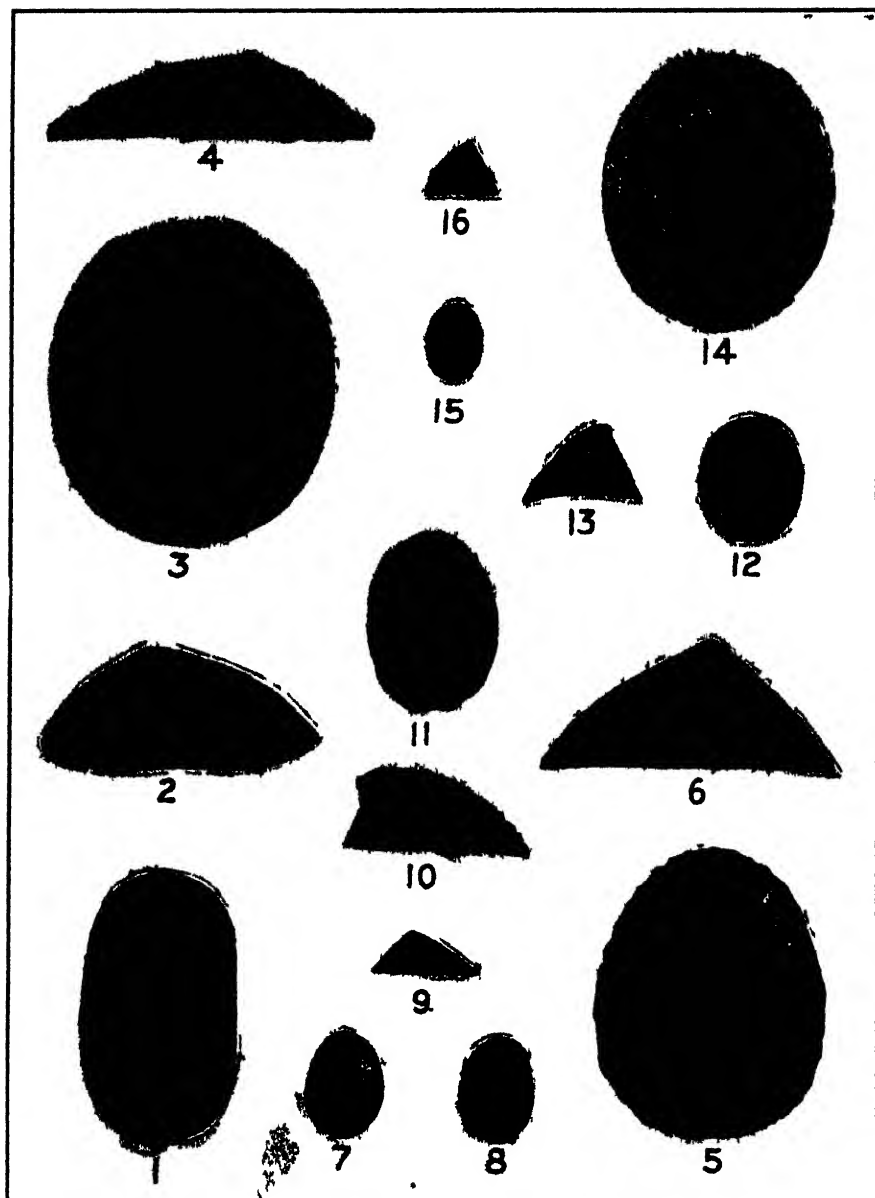


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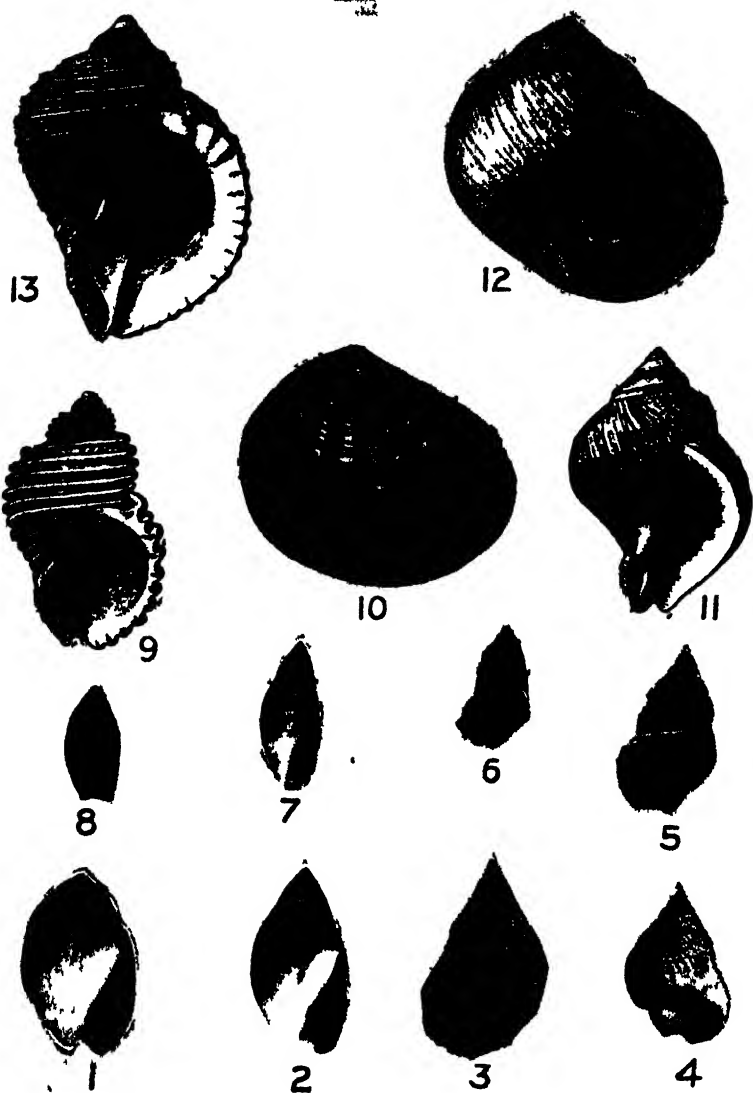


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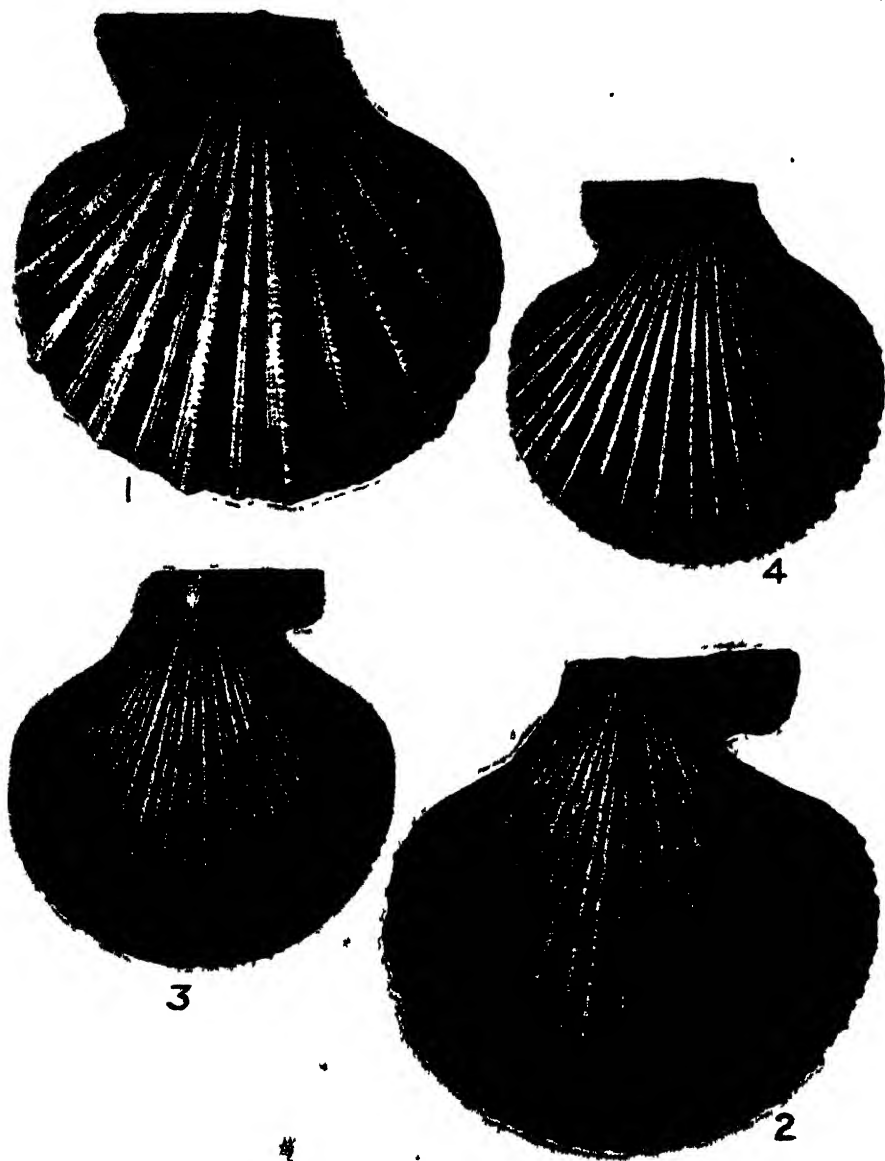


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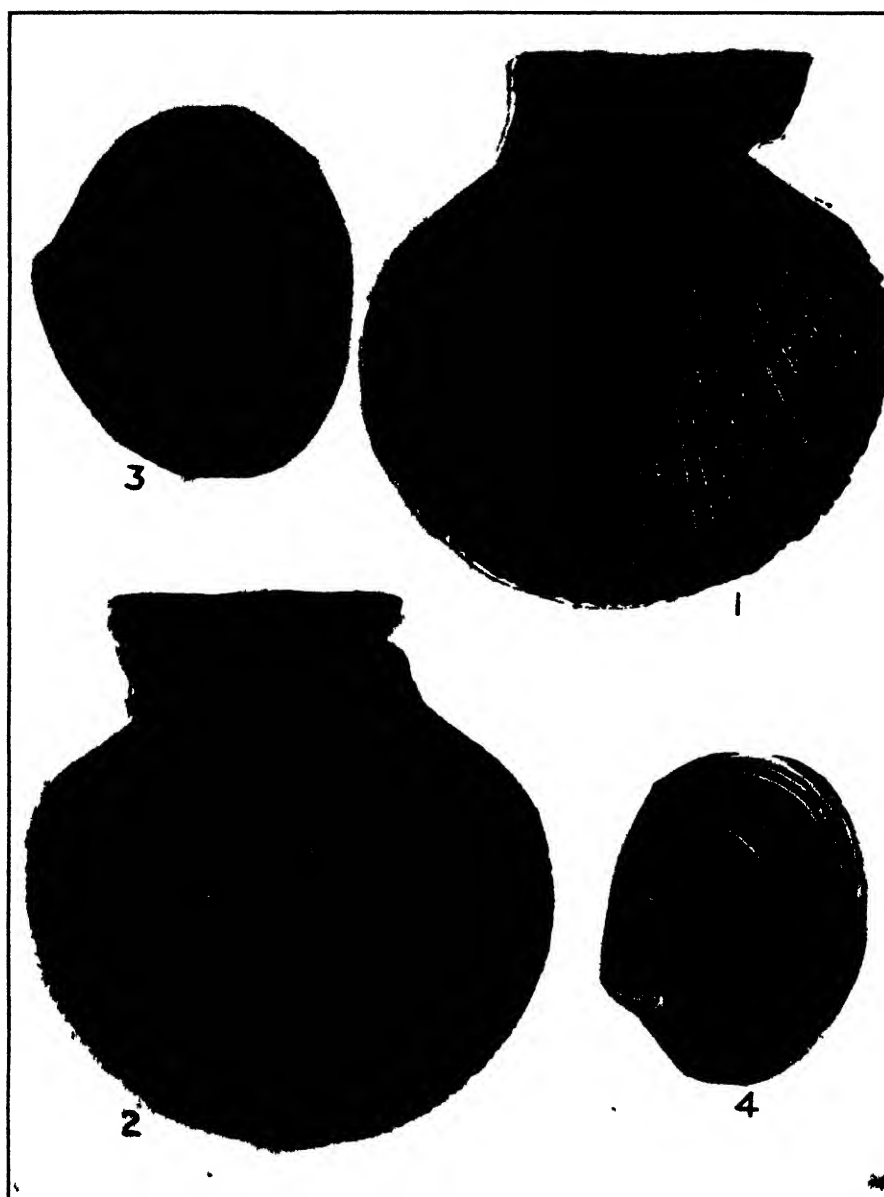


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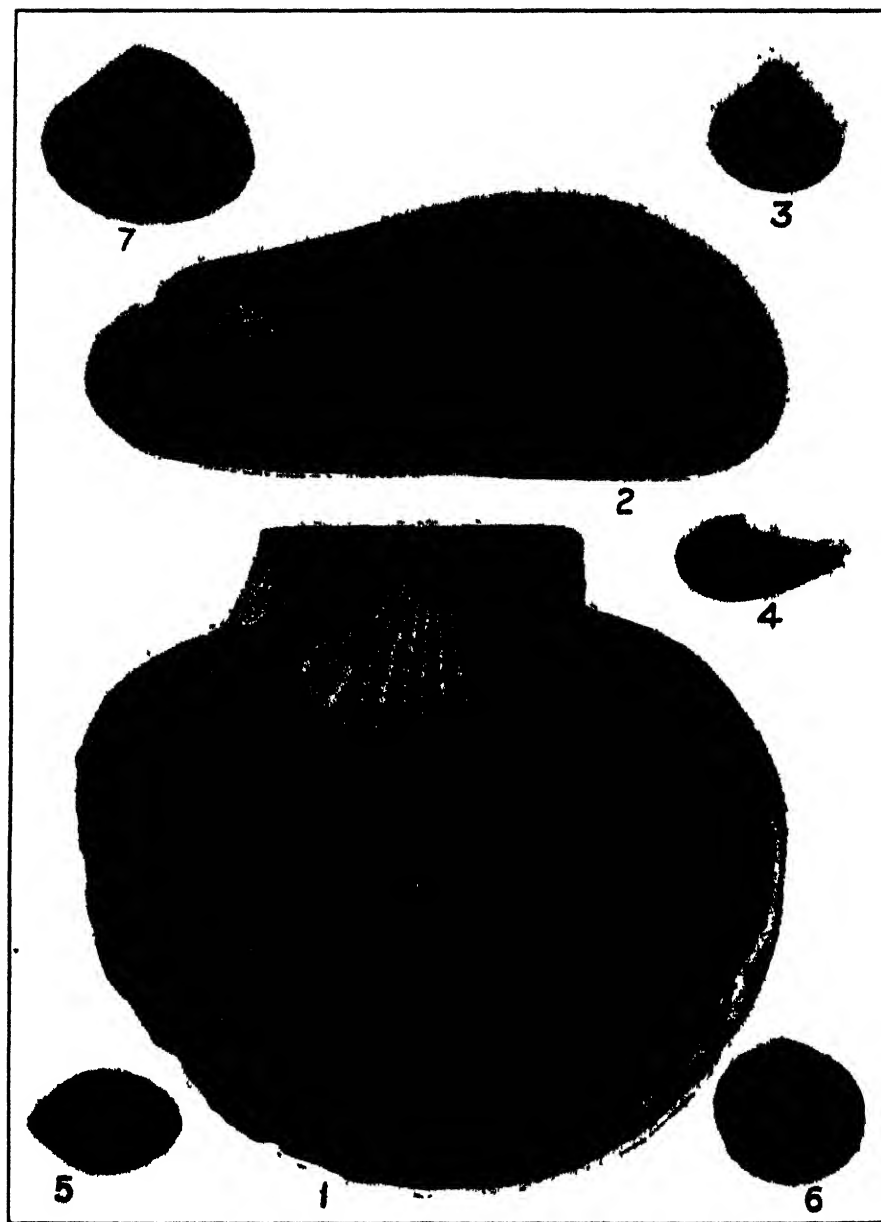


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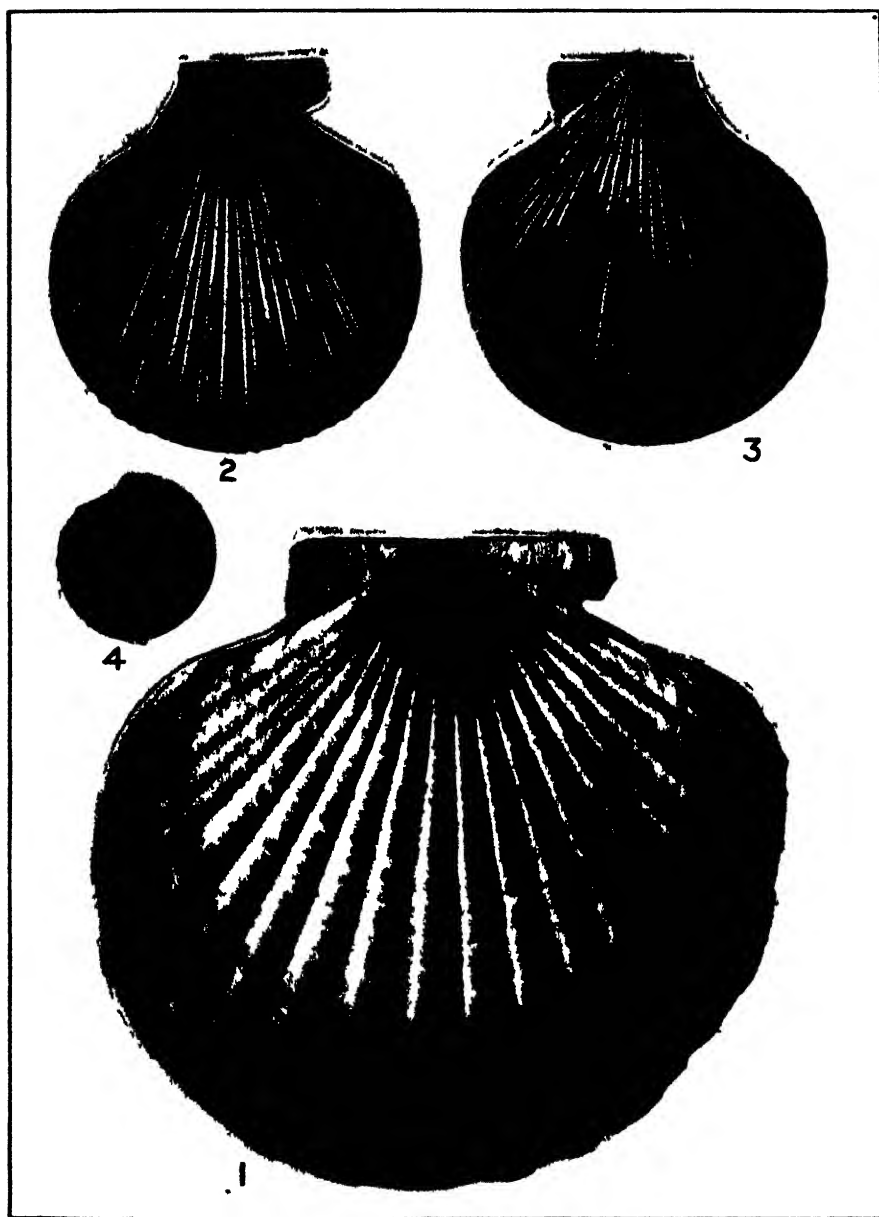


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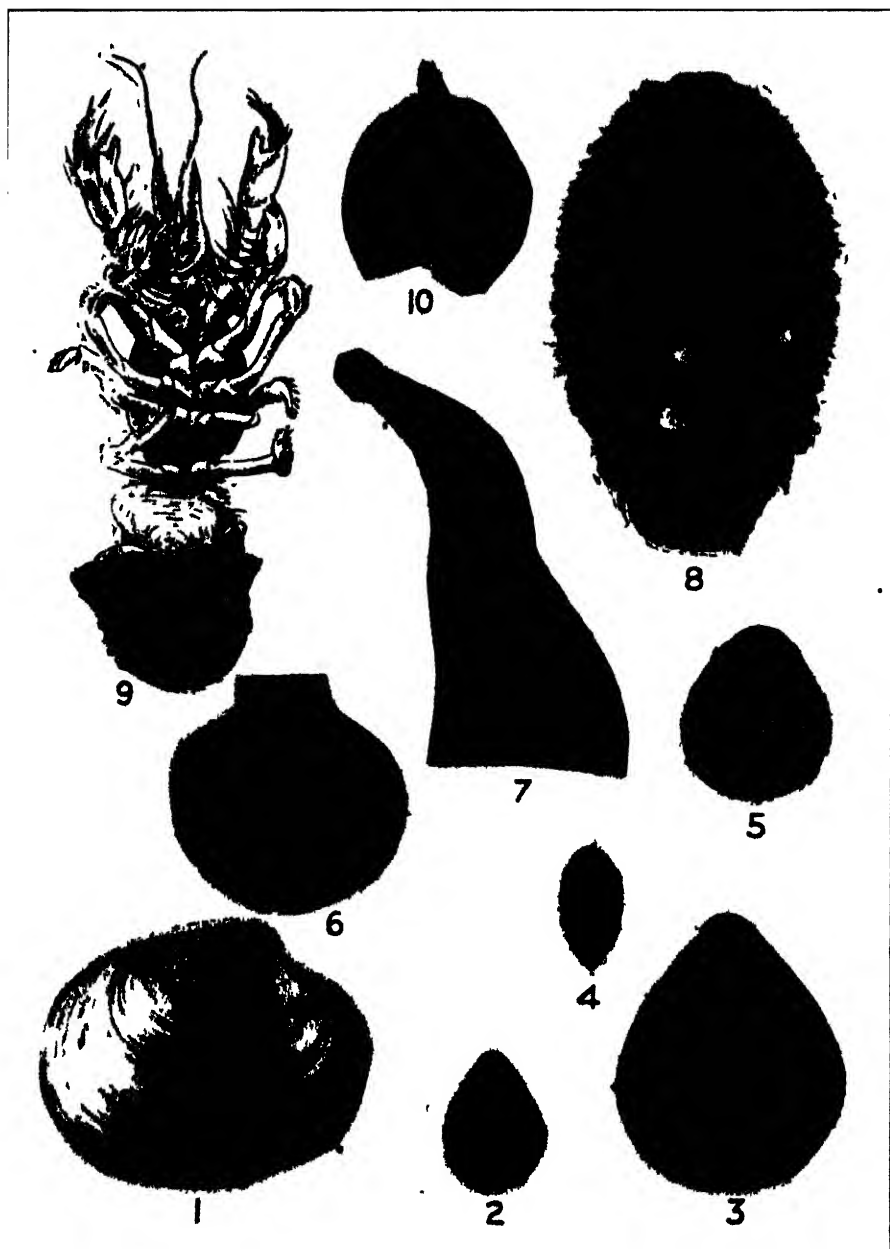


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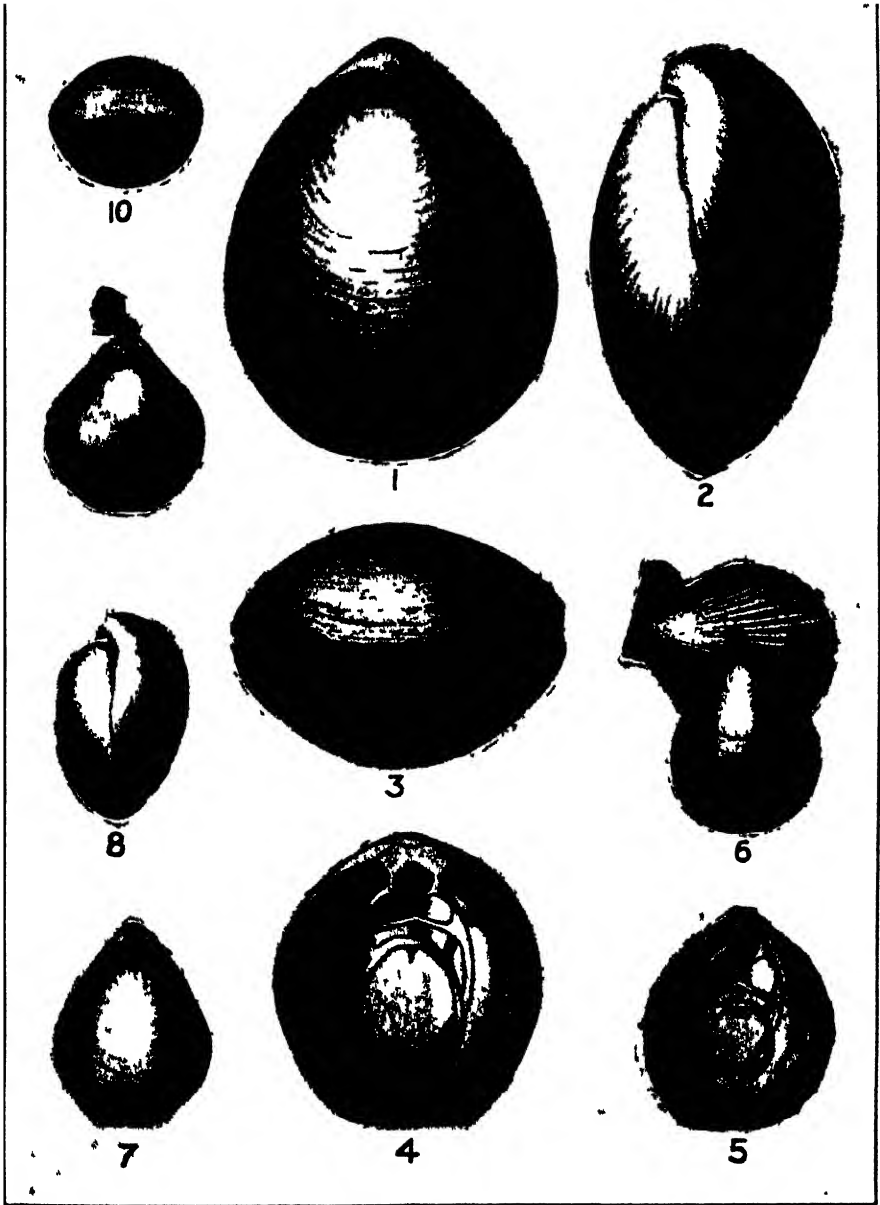


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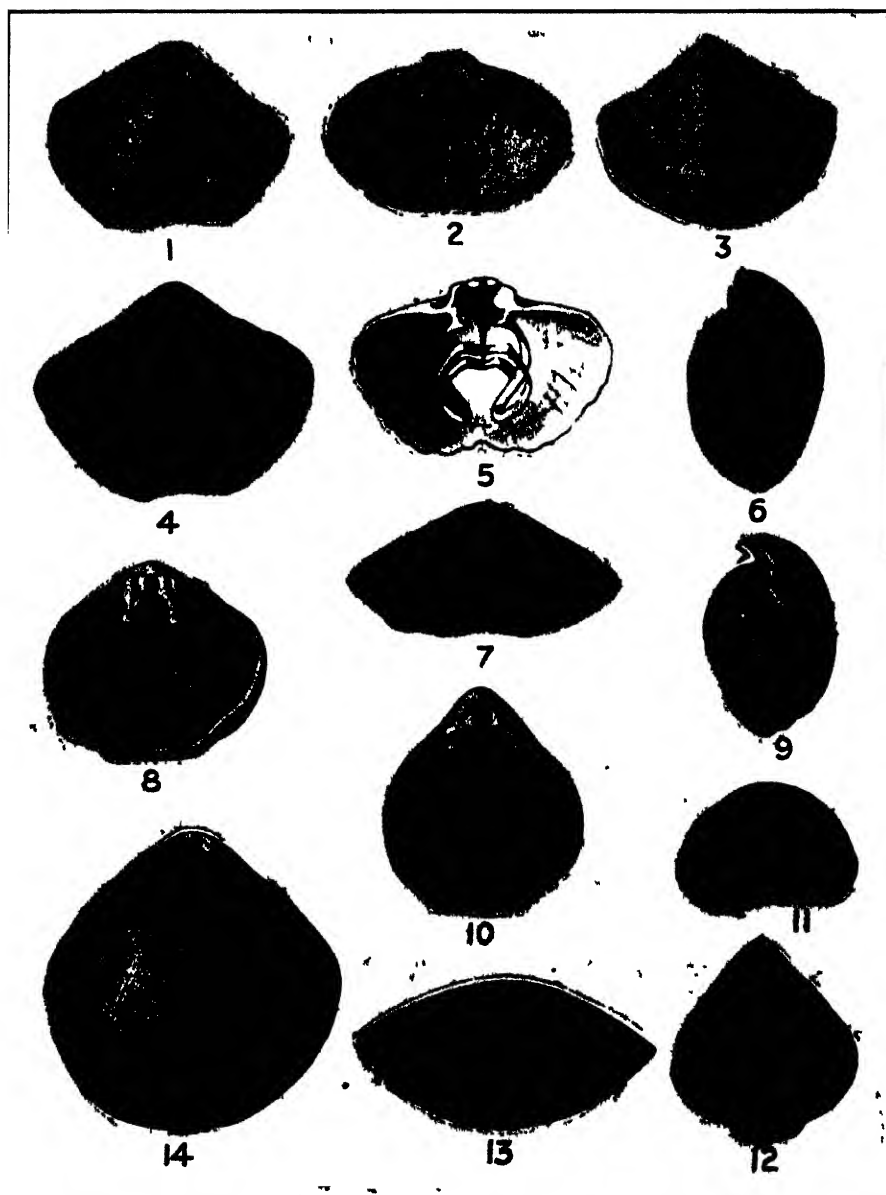
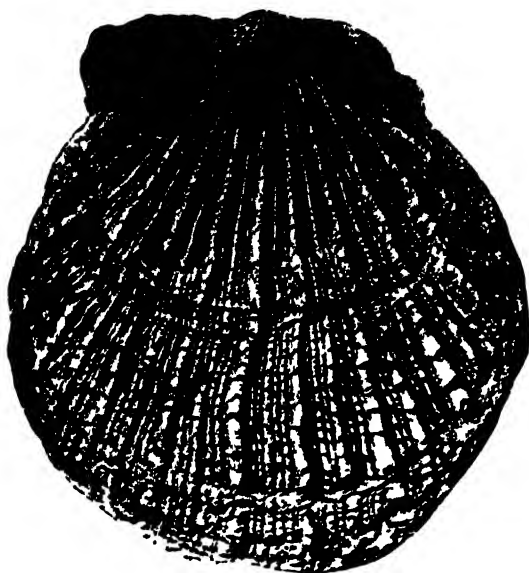


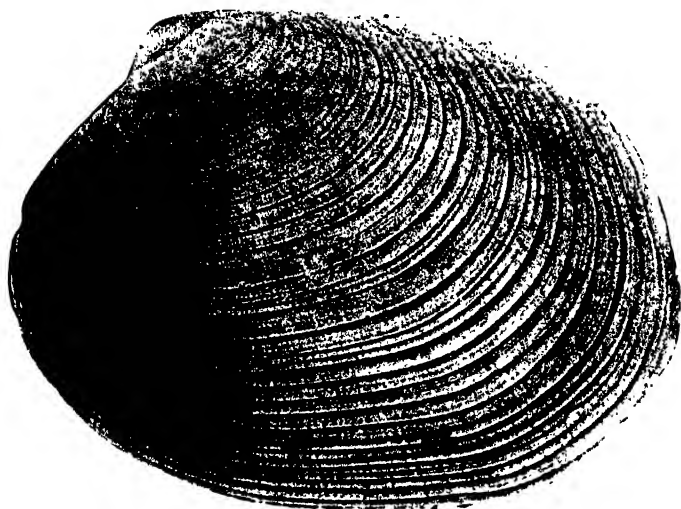
PLATE 29



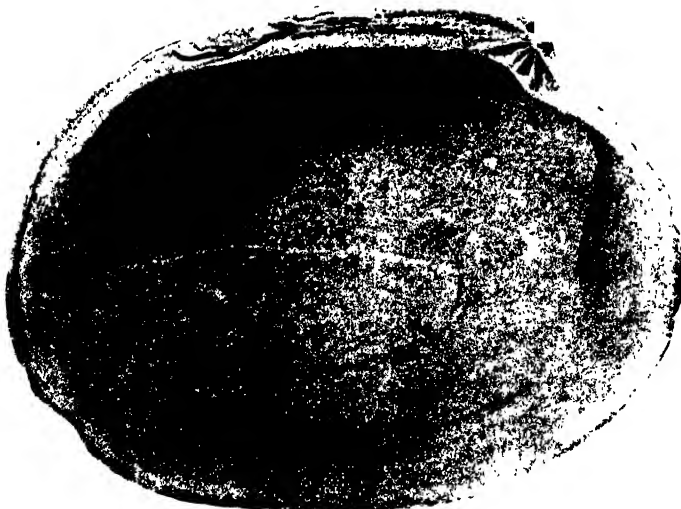
1a



1b



1a



1b



1a



1b



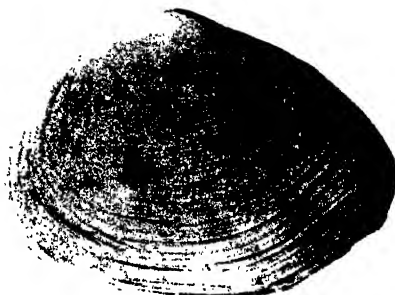
c



1d



a



3a

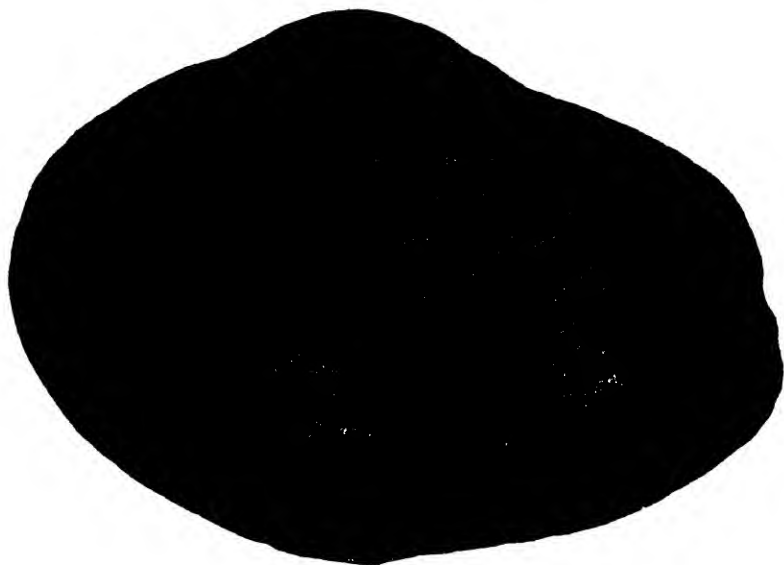


3b



2b





1a



1b



1



2a



2h

PLATE 34



1a



1b



2a



2b



1a



2a



3



1b



4



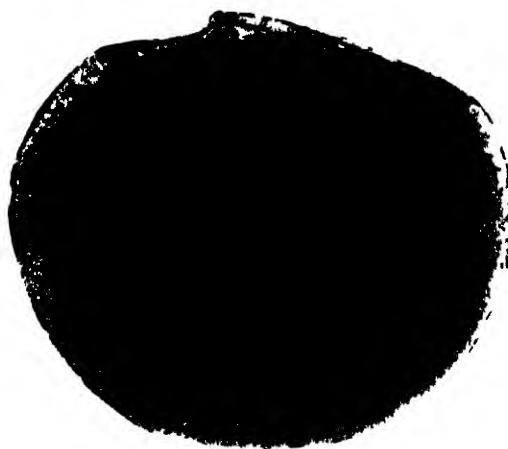
6



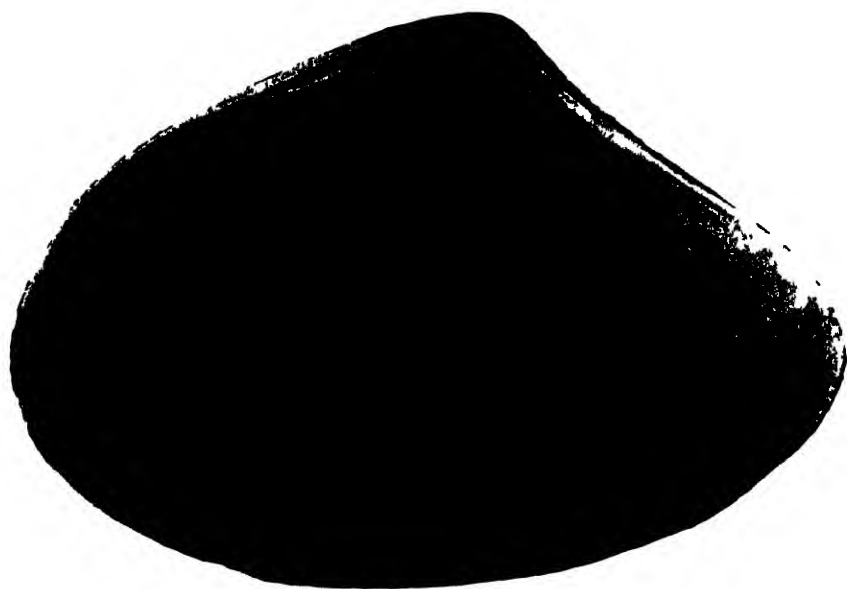
2b



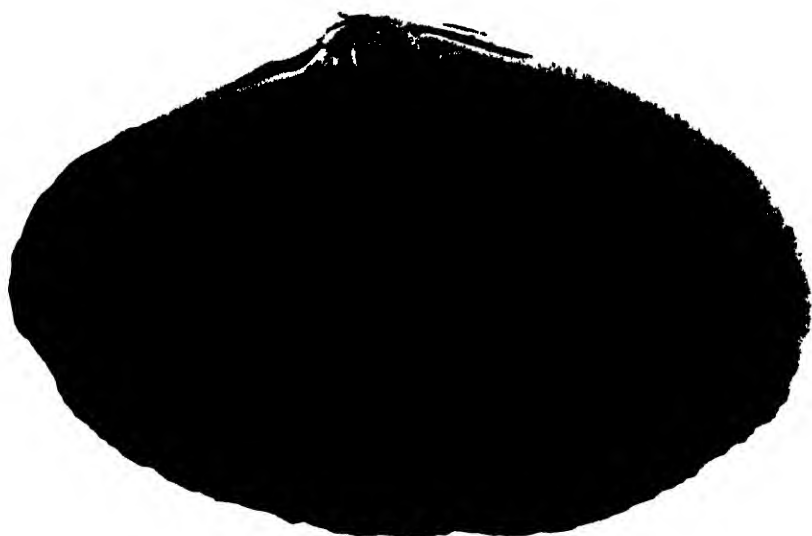
5a



5b



1



2



PLATE 39



1a



2a



1b



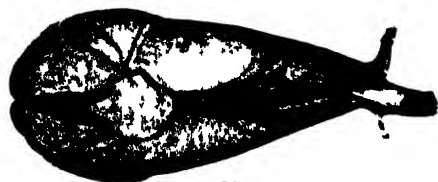
2b



3a



4



3b



5





1a



2



3a



4



5



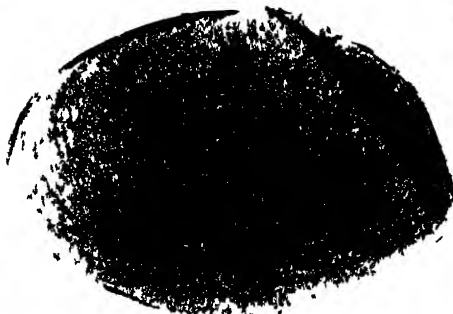
3b



6



7a



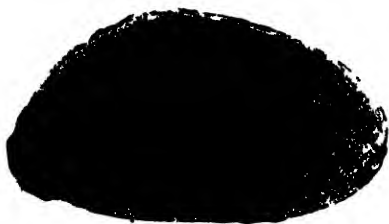
8



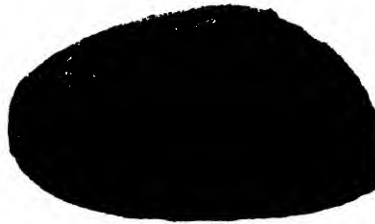
7b



9



10a



10b



1a



1b



2a



3



2b



4



5



2c



2d



6a



6b



1



2



3



4



5a



6



7



5b



8

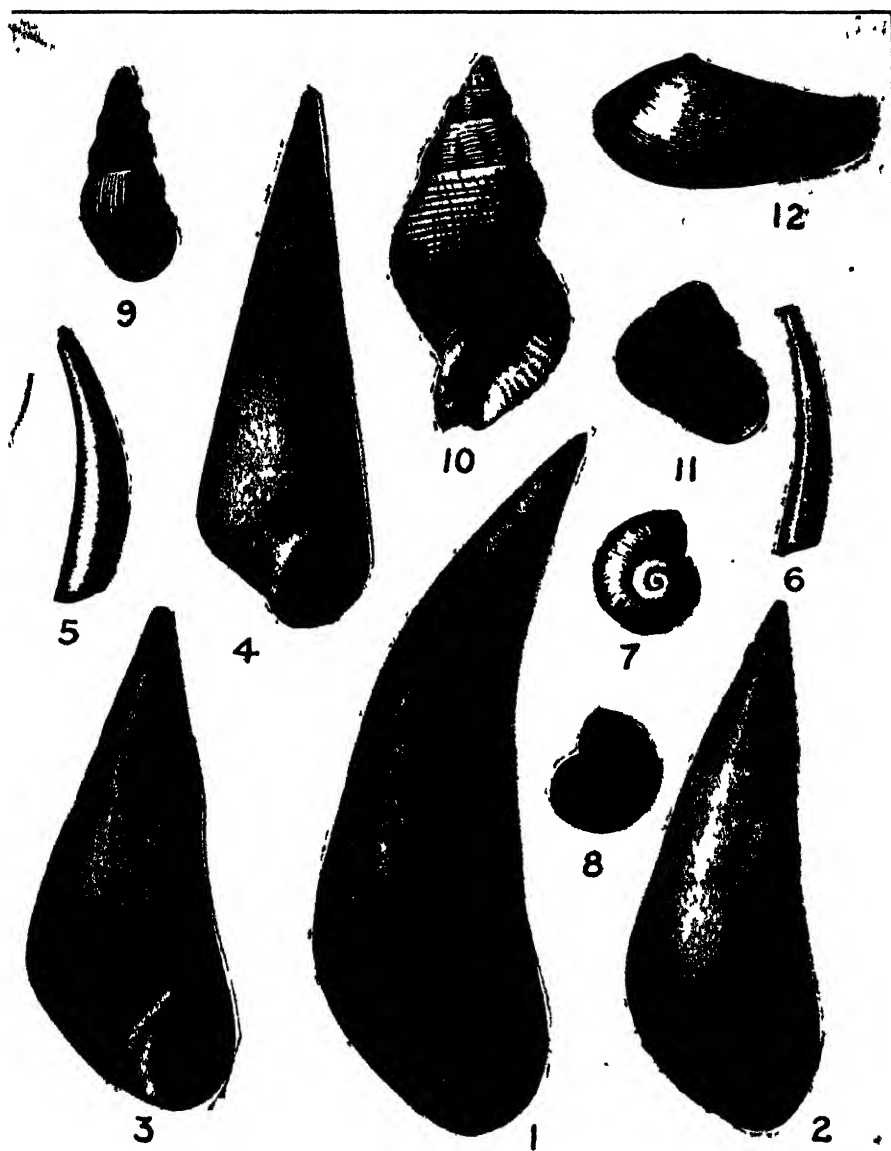


PLATE 44

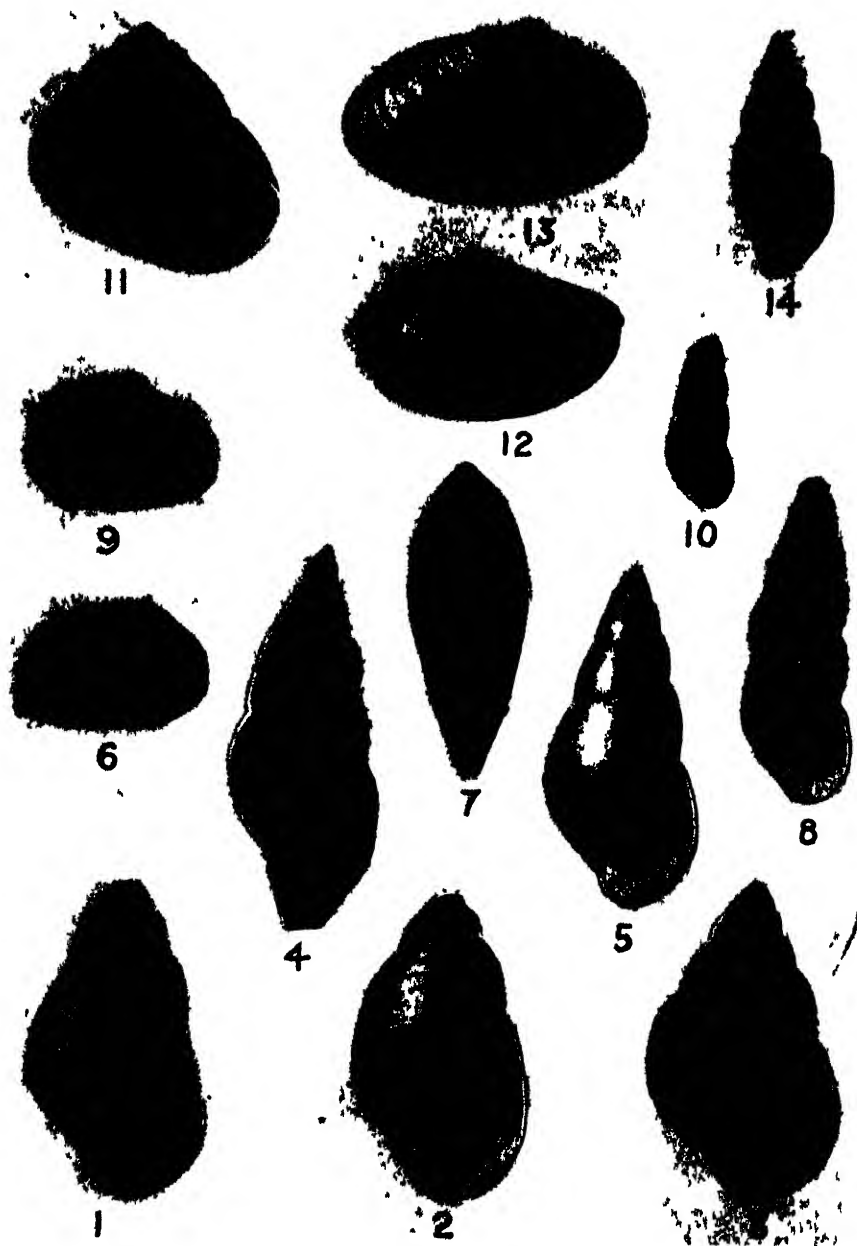


PLATE 45

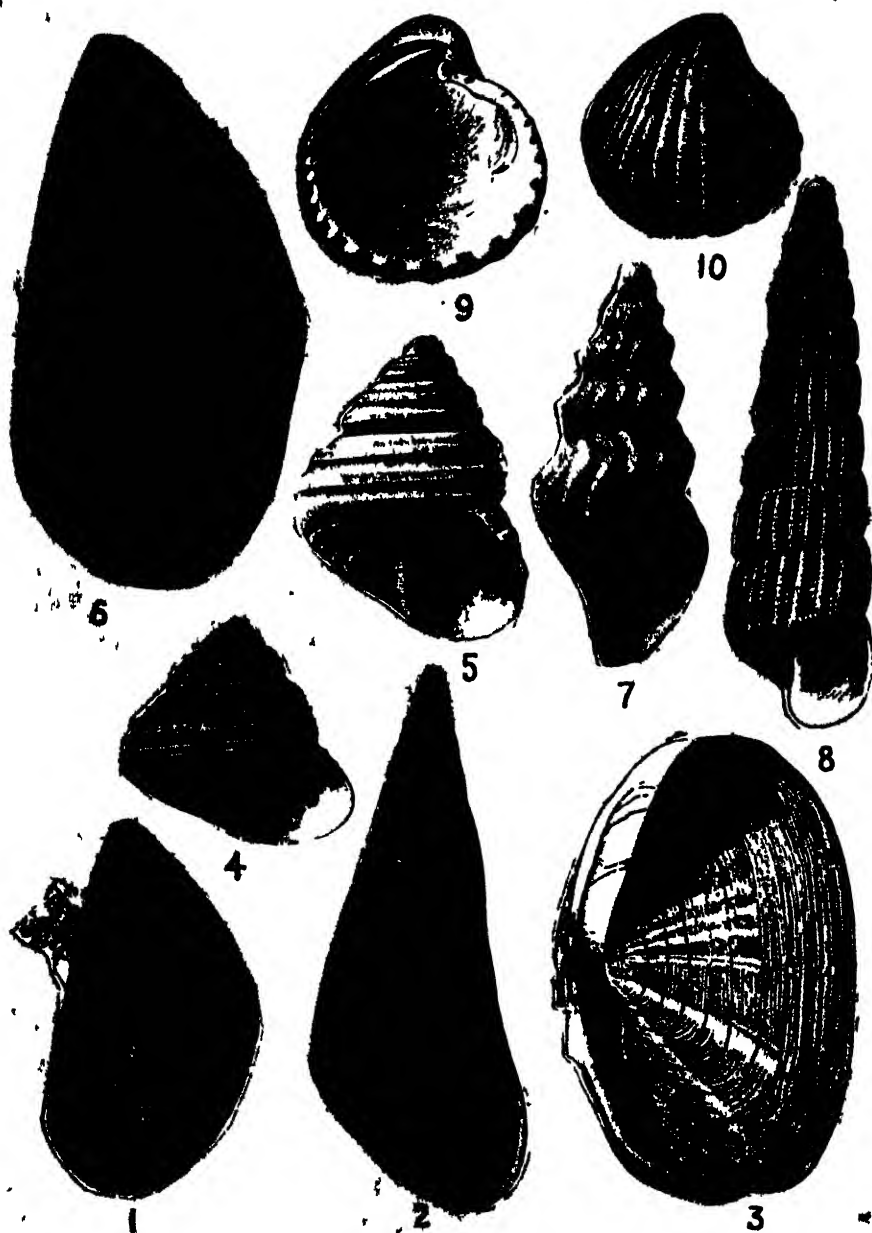


PLATE 46

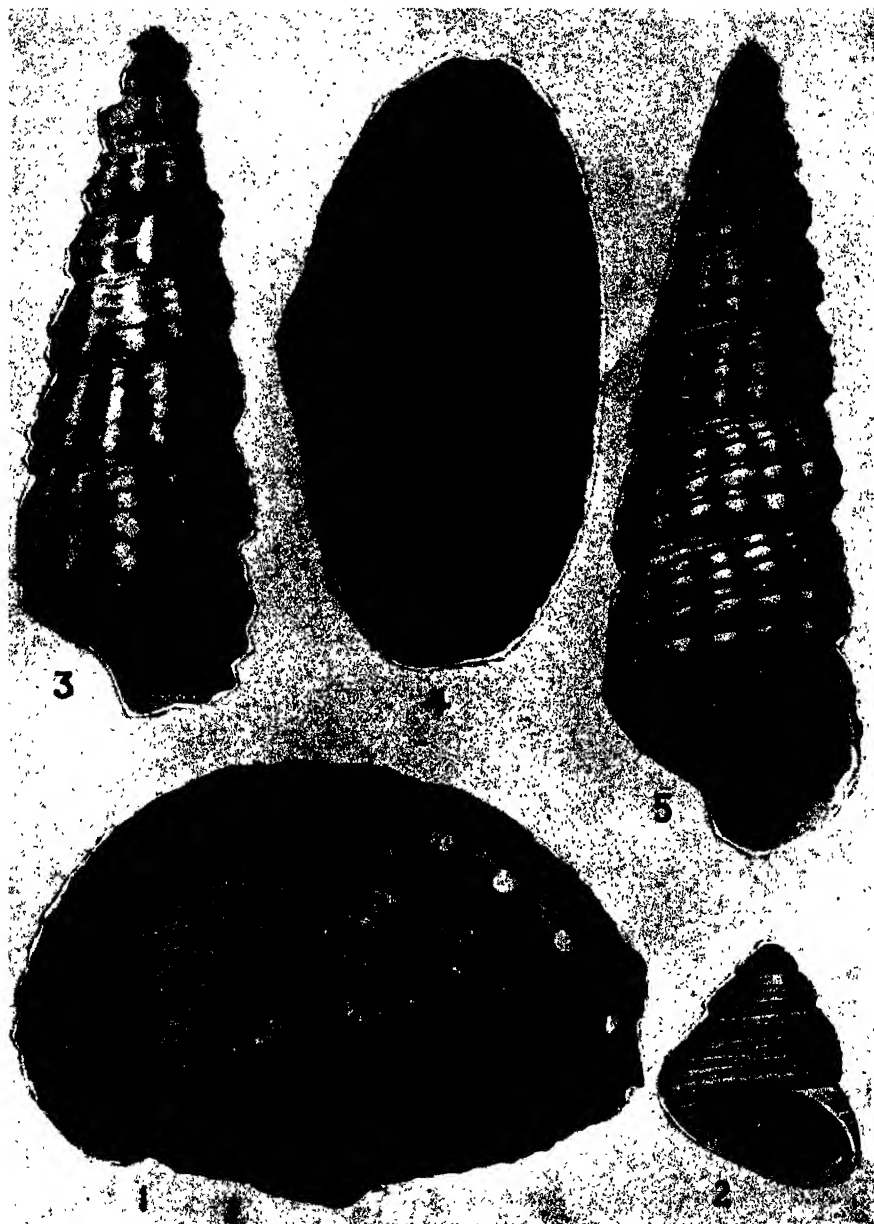


PLATE 47

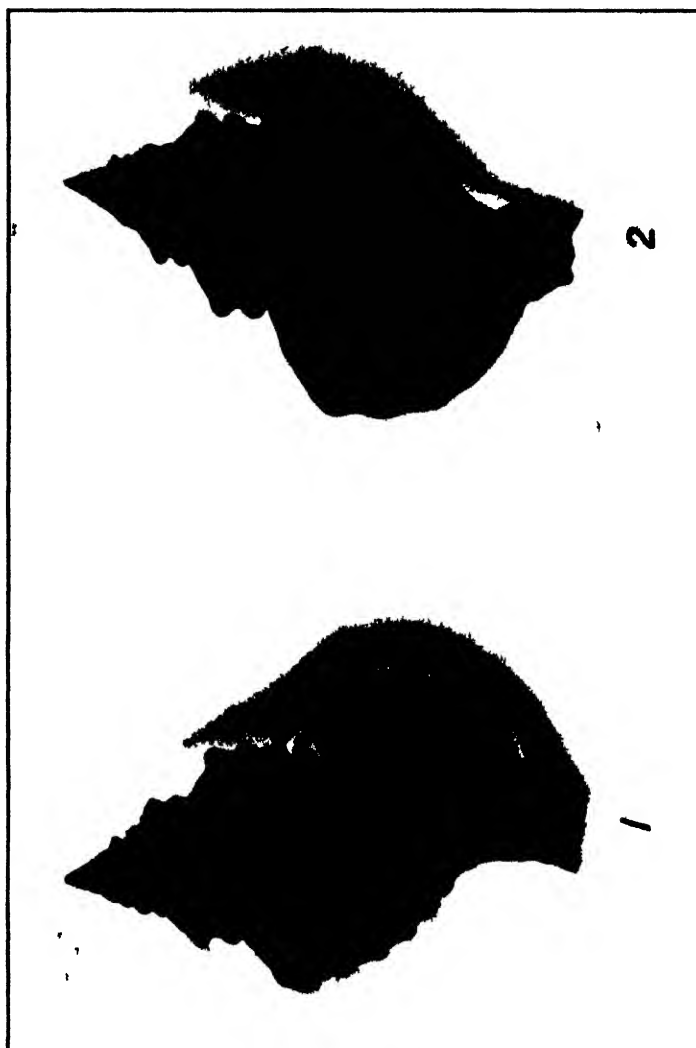


PLATE 48





PLATE 49

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**PRELIMINARY LIST  
OF THE  
UREDINALES OF WASHINGTON**

**By  
JOHN WILLIAM HOTSON**



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## **Preliminary List of the Uredinales of Washington**

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**J. W. HORSON**  
*University of Washington*

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### **INTRODUCTION**

The state of Washington is a very fruitful field for the investigation of rusts. Comparatively little experimental work has been done. There are a number of heteroecious forms, particularly those coming on forest trees, whose alternate hosts are either unknown or imperfectly known. Careful systematic cultural work is a pressing need in order to establish with certainty the complete life cycle of these forms. It is not, however, with this phase of rusts that this article has to do, but rather with their collection and distribution. Many persons have collected rusts in the state and some new ones have been described, but no attempt has been made, even in a preliminary way, to bring together in the form of an annotated-list the results of these collections.

Up to 1918 no list of the rusts occurring in any of the states bordering on the Pacific Coast had been published. In that year Jackson published a rather complete list for the state of Oregon (Brooklyn Bot. Gard. Mem. 1:198-297, 1918). The following years Blasdale published a preliminary list for the state of California (Univ. of Calif. Pub. in Bot. 7:101-157, 1919). The present article is an attempt to bring together the known rusts of the state of Washington, thus completing in a general way the lists for all the Pacific Coast states. There is no claim made that this list is complete or that it even contains all the species that have been collected in the state. It has been prepared with the hope that it may be of use to other workers with rusts in the state in giving at least an approximate idea of the extent and distribution of this order.

### **GENERAL PLAN OF THE PAPER**

The general plan of the paper has been to list alphabetically the genera of the rusts under their respective families, and the species under each genus. Keys to the families and genera are also submitted. The host plants are arranged alphabetically under each species of rust. Following each host-family the spore-forms possessed by the rusts are indicated by symbols. This does not mean that all of these spore-forms have been found in Washington, but they are inserted for the

convenience of those wishing to use the list. Under each host a list of collections is tabulated according to date, giving the locality, collector's name, his number, when possible, and often where the specimens are deposited. The localities are listed in an appendix indicating the county in which they occur.

Those synonyms which appear to be the most useful are placed under each species, but no attempt has been made to make a complete list of them. This may be obtained by consulting the N. Am. Flora at the page cited under each species.

When no collector is indicated the collections were made by the writer. All the collections mentioned have been examined by the writer except those reported from the Arthur Herbarium. Those marked as "Washington Uredineae" are the writer's collection and deposited at the University of Washington, Seattle. This consists of over 1000 specimens from different parts of the state, made by various collectors, and forms a nucleus of an exsiccata of the Uredinales of Washington. This preliminary list is based on over 2000 collections distributed among 224 species. The nomenclature of the host plants is that employed by Piper and Beattie in *The Flora of the Northwest Coast* and the *Flora of Southeastern Washington*.

#### SOURCES OF MATERIAL

The material for this paper has been gleaned from various sources. The writer has had an opportunity of making collections in eastern Washington while working in the Yakima valley, fighting fire blight during the summers of 1914 and 1915; and during the summer of 1919 in the wheat belt, from Spokane to Walla Walla, while employed with the federal government in connection with a survey of smuts and rusts of cereals throughout that region. During the summer of 1922, while helping to combat the White Pine Blister Rust in western Washington the writer had an exceptionally good opportunity for making rust collections. Although these opportunities have contributed several hundred collections from various parts of the state, yet the success and value of the article is largely due to the generous cooperation of other collectors. Perhaps the greatest assistance in this respect was the privilege of looking over and obtaining data of all collections from the state of Washington deposited in the Arthur Herbarium at Purdue University. From this collection data on upwards of 500 collections were obtained. Mr. Wm. N. Suksdorf very generously placed at the writer's disposal his complete collection of rusts, consisting of over 300 specimens. Most of these collections

were made in the southern part of the state. Mr. W. E. Flowers, who collected largely in the vicinity of Spokane, contributed nearly 100 specimens. The collections of C. V. Piper have been obtained from different sources, partly from the herbarium of the Washington State College, partly from the Arthur Herbarium, and partly from those deposited at the University of Washington, at Seattle.

Dr. F. D. Heald very kindly loaned for examination the complete collection of rusts deposited at the Washington State College at Pullman. Collections were also received from Arthur Frank, C. R. Stillinger, J. S. Boyce, G. L. Zundel, E. Bethel, and many others, credit for which has been duly given in each instance.

Professor E. W. D. Holway and Dr. J. R. Wier have collected rather extensively in certain parts of the state, but the writer has had no opportunity of examining these collections except as they occur in one or the other of the herbaria already mentioned.

#### ACKNOWLEDGMENTS

Very grateful acknowledgments are due to Professor H. S. Jackson for making it possible for the writer to obtain the data of specimens collected in Washington and deposited in the Arthur Herbarium; for naming numerous doubtful specimens, for examining the manuscript and offering valuable suggestions concerning it. Helpful suggestions have been received from Jackson's paper on the Uredinales of Oregon, as well as from the published portion of the North American Flora.

The writer is under great obligation also to all those who have contributed specimens for this list, especially those whose names have already been mentioned. He is also indebted to Mrs. Agnes Chase for identification of various grasses and to Dr. K. K. MacKenzie for determining species of *Carex*.

#### SOME CHARACTERISTICS OF RUSTS

The Uredinales include a group of very highly specialized fungi that are capable of growing only on living plants and die with the death of the host. The vegetative stage consists of minute much branched filaments (mycelium) which ramify among the cells of the host, sending suckers (haustoria) into the cells for nourishment. The reproductive phase, which is very complicated, consists of five different types of spores which always follow each other in a definite order (polymorphism). These spores differ from each other in form and size as well as in mode of production. They may all occur on



the same host (autoecism) or certain ones may occur on one host and others on an entirely different one (heteroecism) which usually belongs to a different family widely separated from the first in respect to "blood relationship." It is the determination of the life cycle of these heteroecious forms that is one of the difficult problems in connection with the study of rusts. To increase this difficulty one or more of these spore-forms may be wanting. This fact, connected with their obligate parasitism, heteroecism and polymorphism makes the study of this group one of the most difficult in the whole plant kingdom.

The following are the various spore forms found among the rusts:

1. *Pycnospores* (spermatia) designated by the symbol 0, occur in flask-shaped bodies, known as *pycnia* (spermogonia). These minute bacterium-like bodies, which apparently are functionless, are always associated on the same mycelium with the aecia if the latter are present.
2. *Aeciospores* (aecidiospores) designated by the symbol I, are formed in pustules which are usually more or less cup-shaped, known as *aecia* (aecidia). These spores are one-celled, have a number of germ pores and are formed in chains. On germination they produce mycelia on which urediniospores and teliospores are formed.
3. *Urediniospores* (uredospores) are designated by the symbol II. They are usually formed just below the epidermis which is eventually ruptured. The pustules thus formed are known as uredinia (uredo-sori). These spores are usually produced singly on the ends of short stalks, although occasionally, as in *Chrysomyxa*, they are formed in chains; they are one-celled, similar to the aecidiospores.
4. *Teliospores* (teleutospores), designated by the symbol III, are formed on the same mycelium that produces the urediniospores but usually later in the season. They may be formed singly on the ends of short stalks similar to the urediniospores (Pucciniaceae), or compressed laterally into a cushion-like mass or a column (Melampsoraceae). On germination they usually produce a mycelium of limited growth, with only four cells, known as a basidium (promycelium), each cell of which produces a single spore, a basidiospore (sporidium). In a few species the teliospore on germination simply elongates and divides into four cells, thus forming the basidium on which the four basidiospores are formed (Coleosporia-

ceae). The basidiospores, on germination, produce a mycelium on which aecia and pycnia are formed if the latter are produced at all in the life cycle. The basidiospore is not represented by a symbol because it invariably follows the germination of the teliospore.

In the life cycle of some rusts one or more of these spore forms may be wanting. Arthur in the N. Am. Flora has made use of this fact and has broken up the old, well established genera into long and short cycled forms, giving each of the latter a generic name. There are undoubtedly certain advantages in this system, but the multiplication of new genera and the elimination of many old familiar generic and specific names, like *Puccinia* and *Uromyces*, is unfortunate. Although in general the nomenclature of the N. Am. Flora has been followed, it seems to serve the purpose of this paper best not to follow it in this respect. For convenience of comparison, however, the generic names are given for *Puccinia* and *Uromyces*:

	<i>Puccinia</i>	<i>Uromyces</i>
1. Eu-type, having 0, I, II, III present	<i>Dicaeoma</i>	<i>Negredo</i>
2. Brachy-type, having 0, II, III present	<i>Bullaria</i>	<i>Klebahnia</i>
3. Opsis-type, having 0, I, III present	<i>Allodus</i>	<i>Pucciniola</i>
4. Micro-type, having 0, III present	<i>Micropuccinia</i>	<i>Teleutospora</i>

Examples of all these types will be found in the present list.

Since many of the collectors of Washington rusts do not reside within the state it is highly probable that many collections have been omitted from this list. For this reason a supplementary list will be published as soon as the number of new collections will warrant. If this report should come to the notice of any person who has made collections in any part of the state of Washington, the writer will be glad to receive samples, and due credit will be given for the same.

- A. Teliospores on germination becoming four-celled (internal basidium), compacted laterally into waxy layers; walls of the spores weakly gelatinous  
COLEOSPORIACEAE (p. 279).
- AA. Teliospores germinating by a promycelium (external basidium).
- B. Teliospores compacted laterally into a crust or column (rarely solitary within the tissue); walls of the spores firm.  
MELAMPSORACEAE (p. 281).
- BB. Teliospores free or fascicled; walls of the spores firm or with an outer hygroscopic layer overlaid by cuticle  
PUCCINIACEAE (p. 298).
- AAA. Teliospores unknown  
UREDINALES IMPERFECTI (p. 375).

**COLEOSPORIAACEAE**

Aecia with peridia; telia waxy; teliospores sessile, usually compacted laterally into a cushion-like mass, and at maturity each divided into four superimposed cells, each of which produces a sterigma bearing a basidiospore (internal basidia).

There is only one genus of this family represented in Washington.

**Coleosporium Lev.****1. *Coleosporium occidentale* Arth.**

N. Am. Flora 7:94, 1907.

On COMPOSITAE: II, III. Heteroecious (0, I unknown).

*Senecio hydrophiloides* Rydb. Falcon Valley, Klickitat Co., July 17, 1896, W. N. Suksdorf 530, Wash. Ured. 679, also July 17, 1900, W. N. Suksdorf 586, Wash. Ured. 701.

*Senecio triangularis* Hook. Mt. Adams, Aug. 7, 1885, W. N. Suksdorf 197, Wash. Ured. 548.

**2. *Coleosporium madae* Cooke.**

Grevillea 7:102, 1879; N. Am. Flora 7:92, 1907.

*Stichospora madae* Sydow, Ann. Myc. 2:30, 1904.

*Coleosporium arnicale* Arth. N. Am. Flora 7:94, 1907.

On COMPOSITAE: II, III. Heteroecious (0, I unknown).

*Madia* sp. Falcon Valley, July 30, 1885, W. N. Suksdorf 199, Wash. Ured. 549, also Oct. 30, 1901, W. N. Suksdorf 644, Wash. Ured. 720; Vancouver Lake, Aug. 16, 1894, W. N. Suksdorf 395, Wash. Ured. 647; Friday Harbor, July, 1924, L. Angst, Wash. Ured. 1342.

This disposition of *Coleosporium arnicale* Arth. as a synonym of *Coleosporium madae* Cooke is in accordance with Jackson's arrangement as given in Mycologia 14:114, 1922. The description of *C. arnicale* in 1907 was based on the single collection of W. N. Suksdorf 644, cited above. The host was originally identified as *Arnica foliosa* Nutt. but was interpreted by Arthur as *A. cana* Greene. No other collections of *Coleosporium* on *Arnica* have been reported and there is some doubt as to the validity of the species. Jackson (l. c.) is of the opinion that the host is a species of *Madia* or some close relative.

It is interesting to note that all the species of *Coleosporium* as far as known, have their aecial stage on *Pinus*. Species of this genus with undetermined aecia might, therefore, be looked for as *Perider-*

miums on the leaves of some species of *Pinus*, especially the two-needled pines.

### 3. *Oleosporium solidaginis* (Schw.) Thüm.

Bull. Torrey Club 6:216, 1878; N. Am. Flora 7:90, 1907.

*Uredo solidaginis* Schw. Schr. Nat. Ges. Leipzig 1:70, 1822.

*Peridermium acicolum* Und. & Earle, Bull. Torrey Club 23:400, 1896.

*Peridermium montanum* Arth. & Kern, Bull. Torrey Club 33:413, 1906.

On PINACEAE: 0, I. Heteroecious.

*Pinus contorta* Dougl. Bingen, May 3, 1913, W. N. Suksdorf 1062, Wash. Ured. 760; Locke, May 26, 1918, W. E. Flowers 6175, Wash. Ured. 2570.

On COMPOSITAE: II, III.

*Aster eatoni* (Gray) Howell. Seattle, Sept., 1872, C. V. Piper 64, Herb. W. S. C., Wash. Ured. 1289.

*Aster fremonti* (T. & G.) Gray. Waitsburg, Oct. 8, 1899, R. M. Horner 1405, Herb. W. S. C., Wash. Ured. 1820, also collected by G. L. Zundel Oct. 7, 1922, Wash. Ured. 1319.

*Aster laevis geyeri* Gray. Colfax, Aug. 25, 1898, C. V. Piper 636, Herb. W. S. C.

*Aster punicens* L. Spokane, Sept. 20, 1914, W. E. Flowers, 6055, Wash. Ured. 2539.

*Grindelia oregana* Gray. Rolling Bay, Oct. 9, 1921. Wash. Ured. 203; Winslow, June 20, 1922, Wash. Ured. 1174.

*Grindelia* sp. Langley, Sept. 1922, J. M. Grant, Wash. Ured. 305.

*Solidago elongata* Nutt. Mt. Adams, Aug. 8, 1886, W. N. Suksdorf 274, Wash. Ured. 585; Lacey, July 2, 1921, A. Frank 72, Wash. Ured. 415.

*Solidago missouriensis* Gray. Pullman, July 14, 1894, C. V. Piper 241, Herb. W.S.C., Arth. Herb., also by G. L. Zundel, Sept. 13, 1920, Wash. Ured. 1275; Spokane, Aug. 10, 1913, W. E. Flowers 6121, Wash. Ured. 2554.

*Solidago serotina* Ait. Waitsburg, Oct. 13, 1899, R. M. Horner 1413, Herb. W.S.C.

*Solidago tolmieana* Gray. Lacey, July 2, 1921, A. Frank, Wash. Ured. 416.

*Solidago* sp. Pullman, Sept. 11, 1918, B. F. Dana, Herb. W.S.C. 530, Wash. Ured. 1291.

**MELAMPSORACEAE**

Teliospores sessile, compacted laterally into a more or less definite crust or column, rarely solitary within the tissues (Uredinopsis); on germination they produce a promycelium (basidia external).

- A. Telia indehiscent; teliospores not in chains.
- B. Teliospores 2-4-celled, formed by vertically intersecting septa.
- C. Telia on ferns; teliospores colorless or yellowish, scattered singly in host tissue or formed in the epidermal cells.
- D. Teliospores intercellular, scattered within the mesophyll; uredinium with a peridium; urediniospores pointed, colorless, without germ pores; pycnia subcuticular.  
UREDINOPSIS (p. 296).
- DD. Teliospores intracellular; urediniospores not pointed; pycnia subepidermal.
- E. Uredinia with a peridium; urediniospores colorless, without evident germ-pores  
MILEsia (p. 293).
- EE. Uredinia without or with a very rudimentary peridium; urediniospores yellowish with germ-pores  
HYALOPSORA (p. 287).
- CC. Telia on seed-plants; teliospores brownish in the epidermal cells or forming subepidermal crusts.
- F. Teliospores intracellular, in swollen epidermal cells; life cycle with 0, I, III.  
CALYPTOSPORA (p. 282).
- FF. Teliospores intercellular, subepidermal; not forming swollen epidermal cells; life cycle with 0, I, II, III  
PUCCINIASTRUM (p. 294).
- BB. Teliospores one-celled, united into a cushion-like mass.
- G. Teliospores in the epidermal cells, hyaline or faintly colored; uredinium with a peridium but without paraphyses; urediniospores without evident pores; aecium with a peridium.  
MELAMPSORELLA (p. 292).
- GG. Teliospores not intracellular, brown.
- H. Telia subepidermal or subcuticular; uredinium without a peridium but with paraphyses; aecium of the *Caeoma*-type.  
MELAMPSORA (p. 288).
- HH. Telia subepidermal; uredinium with a peridium but without paraphyses; aecium with a peridium.  
MELAMPSORIDIUM (p. 293).
- AA. Telia erumpent, all the sori subepidermal; teliospores in chains.

- I. Teliospores compacted laterally into a more or less cushion-like mass; urediniospores in chains. **CHRY SOMYXA** (p. 282).  
 II. Teliospores compacted laterally into a column; urediniospores borne singly on pedicels **CRONARTIUM** (p. 284).

### **Calyptospora Kühn**

#### **4. Calyptospora columnaris** (Alb. & Schw.) Kühn.

Rab.—Wint. Fungi Eur. 3521, 1886, (Hedwigia 26:28, 1887); N. Am. Flora 7:114, 1907.

*Aecidium columnare* Alb. & Schw. Consp. Fung. 121, 1805.

*Calyptospora geoppertiana* Kuhn, Hedwigia 8:81, 1869.

On PINACEAE: 0, I. Heteroecious.

*Abies amabilis* (Loud.) Forb. Mt. Rainier, Sept. 26, 1915, C. H. Kauffman 7, Arth. Herb.; Lake Cushman, Olympic Mts., Oct. 25, 1915, C. H. Kauffman, Arth. Herb.; Big Four, Aug. 23, 1921, J. S. Boyce 65, Arth. Herb.

*Abies lasiocarpa* (Hook.) Nutt. Locke, Aug. 27, 1917, W. E. Flowers 6586, Wash. Ured. 1130.

On VACCINIACEAE: III.

*Vaccinium macrophyllum* (Hook.) Piper. Locke, Aug. 5, 1915, W. E. Flowers 6393, Wash. Ured. 1131; Silverton, July 7, 1920, C. R. Stillinger 738, Wash. Ured. 850.

*Vaccinium ovalifolium* Smith. Silverton, July 8, 1920, C. R. Stillinger 734, Wash. Ured. 837.

*Vaccinium ovatum* Push. Bainbridge Is., Aug. 3, 1909, E. Bartholomew, Barth. N. Am. Ured. 403, Barth. Fungi Columb. 3104, Arth. Herb.; Seattle, Sept. 23, 1916, W. E. Flowers 6119, Wash. Ured. 2552; Shelton, Sept. 23, 1918, Wash. Ured. 335; Winslow, Oct. 18, 1918, Wash. Ured. 82; Olympic Mts., July, 1919, Grace Howard, Wash. Ured. 336; Langley, March, 1922, J. M. Grant, Wash. Ured. 296; Chico, May 30, 1922, Maxine Wilkes, Wash. Ured. 964; Vashon Island, Oct. 2, 1922, Wash. Ured. 1069; Lake Quinault, Oct., 1922, E. Bethel; Quilcene, Nov. 15, 1922, E. Bethel, Wash. Ured. 1078.

*Vaccinium parviflorum* Smith. Seattle, Oct., 1891, C. V. Piper, Arth. Herb., Wash. Ured. 2880; Glacier, July and Oct., 1922, E. Bethel.

*Vaccinium* sp. Paradise Valley, Mt. Rainier, Aug. 23, 1901, E. W. D. Holway, Arth. Herb.

### **Chrysomyxa Unger**

#### **5. Chrysomyxa ledicola** Lagerh.

Tromso. Mus. Aarsh. 16:119. 1893.

*Uredo ledicola* Peck, Ann. Rep. N. Y. State Mus. 25:90. 1873.

*Peridermium decolorans* Peck, Ann. Rep. N. Y. State Museum 27: 104, 1875.

*Melampsoropsis ledicola* (Peck) Arth. Result. Sci. Congr. Bot. Vienne 338. 1906; N. Am. Flora 7:119. 1907.

On PINACEAE: 0, I. Heteroecious.

*Picea sitchensis* (Bong.) T. & M. Bainbridge Island, July 29, 1909, E. Bartholomew, Barth. Fungi Columb. 3152, Arth. Herb.; Ilwaco, July, 1918, Wash. Ured 84.

On ERICACEAE: II, III.

*Ledum groenlandicum* Oeder. Seattle, June, 1892, C. V. Piper 74, Arth. Herb., Wash. Ured. 2881; Mt. Rainier, Aug. 31, 1901, E. W. D. Holway, Arth. Herb.; Ronald, July 7, 1910, T. C. Frye, Arth. Herb., Wash. Ured. 71; Seattle, May 19, 1915, Arth. Herb., Wash. Ured. 330; Granite, July 5, 1920, C. R. Stillinger 744, Wash. Ured. 847; Woodinville, Nov. 6, 1921, T. C. Frye, Wash. Ured. 224; Friday Harbor, July, 1922, L. Hartge, Wash. Ured. 1000.

**6. *Chrysomyxa piperiana* (Arth.) comb. nov.**

*Melampsoropsis piperiana* Arth. N. Am. Flora 7:120, 1907.

On ERICACEAE: II. (0, I and III unknown).

*Rhododendron californicum* Hook. Seattle, May 6, 1892, C. V. Piper, Arth. Herb. (type collection), also June, 1914, Wash. Ured. 967; Duckabush River, Aug. 12, 1912, E. Bartholomew 4843, Arth. Herb.; Spokane, Aug. 30, 1912, W. E. Flowers 6407, Wash. Ured. 1110; Charleston, May 22, 1921, Grace Howard, Wash. Ured. 196; Langley, May, 1922, Alexia Reuter, Wash. Ured. 973; Chico, May, 1922, L. Sundquist, Wash. Ured. 969; Port Orchard, July, 1922, Wash. Ured. 1010; Seabeck, July, 1922, Wash. Ured 1011; Olalla, July, 1922, Wash. Ured. 1003; Holly, July, 1922, Wash. Ured. 1009; Silverdale, July, 1922, Wash. Ured. 1007; Port Gamble, July, 1922, Wash. Ured. 1005; Kingston, July, 1922, Wash. Ured. 1008; Dewatto, July, 1922, Wash. Ured. 1006; Shelton, July, 1922, Wash. Ured. 1004; Port Townsend, Jan. 5, 1924, P. S. Simcoe, Wash. Ured. 1284.

**7. *Chrysomyxa pirolae* (D.C.) Rostr.**

Bot. Centr. 3:126. 1881.

*Pcridermium conorum piceae* Arth. and Kern. Bull. Torrey Club. 33:431. 1906.

*Melampsoropsis pyrolae* (DC) Arth. Result. Sci. Congr. Bot. Vienne 338. 1906; N. Am. Flora 7:118. 1907.

On PYROLACEAE: II, III. (0, I unknown).

*Moneses uniflora* (L.) Gray. North Cove, Apr. 15, 1908. T. C. Frye, Arth. Herb.

*Pyrola bracteata* Hook. Locke, June 16, 1916. W. E. Flowers 6176, Wash. Ured. 2571; Mt. Adams, July 27, 1895. W. N. Suksdorf 463, Wash. Ured. 675.



*Pyrola chlorantha* Swartz. Hillyard, Aug. 7, 1913, W. E. Flowers 6359, Wash. Ured. 1126; also July 7, 1914, Wash. Ured. 2575.

*Pyrola secunda* L. Locke, June 20, 1917, W. E. Flowers 6064, Wash. Ured. 2543.

### **Cronartium Fries**

#### **8. Cronartium coleosporioides (Dietel & Holway) Arth.**

N. Am. Flora 7:123. 1907.

*Peridermium filamentosum* Pk. Bot. Gaz. 7:56. 1882.

*Peridermium harknessii* Moore, Bull. Calif. Acad. Sci. 1:37. 1884.

*Uredo coleosporioides* Dietel & Holway, Erythea 1:247. 1893.

*Peridermium stalactiforme* Arth. & Kern. Bull. Torrey Club, 33:419. 1906.

*Cronartium filamentosum* (Pk.) Hedgcock, Phytopath. 2:177. 1912.

On PINACEAE: 0, I. Heteroecious.

*Pinus contorta* Dougl. Chiquash Mts., Aug. 12, 1886, W. N. Suksdorf 302, Wash. Ured. 588; Locke, May 30, 1916, W. E. Flowers 6390, Wash. Ured. 1109; Mt. Adams, July, 1922, Ed. S. Meany, Wash. Ured. 1269.

*Pinus ponderosa* Dougl. Cascade Mts., Aug., 1918, Wash. Ured. 1338.

On SCROPHULARIACEAE: II, III.

*Castilleja miniata* Dougl. Skamania Co., Aug. 10, 1886, W. N. Suksdorf, Arth. Herb.

*Pedicularis surrecta* Benth. Locke, W. E. Flowers 6376, Wash. Ured. 1129.

Our knowledge of the life cycle of this rust is somewhat uncertain. Conflicting reports are found, and until successful infection experiments have been carried out it is almost impossible to clear up the situation. There are at least two caulicolous, non-gall-forming species of *Peridermium*, both of which have their telial stage on *Castilleja*.

All the records given above are of the gall-forming type of aecia.

#### **9. Cronartium occidentale Hedgc., Bethel & Hunt.**

Jour. Agric. Res. 14:413, 1918.

On SAXIFRAGACEAE: II, III. Heteroecious (0, I on Pinaceae).

*Ribes aureum* Pursh. West of Spokane, Aug. 12, 1912, W. E. Flowers 6415, Wash. Ured. 1178.

*Ribes odoratum* Wendl. Spokane, Oct. 20, 1914, W. E. Flowers 6360, Wash. Ured. 1179.

This is the piñon blister rust, which resembles very closely the white pine blister rust, except that the aecia occur on the 1- and 2-needled pines, while the latter occurs on the 5-needled pines.

**10. *Oronartium pyriforme* (Pk.) Hedgc. & Long.**

Alt. Stage of *Peridermium pyriforme* 3. 1914.

*Peridermium pyriforme* Peck, Bull. Torrey Club 6:13. 1875.

*Oronartium comandrae* Peck, Bull. Torrey Club 11:50. 1884.

*Peridermium betheli* Hedgc. & Long, Phytopath. 3:251. 1913.

On PINACEAE: 0, I. Heteroecious.

*Pinus ponderosa* Dougl. Wenatchee, May, 1914, D. F. Fisher 12467, Forest Pathology, Washington, D.C.; Locke, May 21, 1915. W. E. Flowers 6418, Wash. Ured. 1113; Spokane, June 11, 1919, W. E. Flowers 6191, Wash. Ured. 1114 also May 22, 1921, F. D. Heald, Herb. W.S.C. 765.

On SANTALACEAE: II, III.

*Comandra pallida* DC. Newport, Aug., 1915, J. R. Weir, Barth., N. Am. Ured. 1711; Locke, Sept. 13, 1915, W. E. Flowers 6341, Wash. Ured. 1166.

*Comandra umbellata* (L.). Nutt. Trout Lake, July, 1884, W. N. Suksdorf 176, Wash. Ured. 1321; Bingen, Sept. 21, 1904, C. V. Piper Herb. W.S.C.

**11. *Oronartium ribicola* Fisch. de Waldh.**

Rab. Fungi Eur. 1595 (Hedwigia 11:182) 1872; N. Am. Flora 7:122. 1907.

*Peridermium strobis* Kleb. Abh. Nat. Ver. Bremen 10:153. 1887.

On PINACEAE: 0, I. Heteroecious.

*Pinus strobus* L. Everett, Nov. 20, 1921, H. N. Putnam; Blaine, July 11, 1922, W. S. Smith.

*Pinus monticola* Dougl. Quilcene, April 14, 1924, H. N. Putnam, Bur. Pl. Ind. Blister Rust Control; De Lions, Apr. 15, 1924, H. N. Putnam, Bur. Pl. Ind. Blister Rust Control; Sumas, April 17, 1924, H. N. Putnam, Bur. Pl. Ind. Blister Rust Control.

On SAXIFRAGACEAE: II, III.

*Ribes bracteosum* Dougl. Quilcene, Aug. 16, 1922, C. H. Johnson, Wash. Ured. 890; Port Ludlow, Sept. 9, 1922, Wash. Ured. 913; Woodman, Sept. 13, 1922, Wash. Ured. 914; Hadlock, Sept. 14, 1922, Wash. Ured. 915; Snow Creek, Sept. 15, 1922, P. S. Simcoe, Wash. Ured. 888; Junction, Sept. 15, 1922, P. S. Simcoe, Wash. Ured. 1268; Chimacum, Sept. 15, 1922, Wash. Ured. 918; De Lions, Sept. 15, 1922, Wash. Ured. 919; Discovery Bay, Sept. 15, 1922, Wash. Ured. 916; Lake Croker, Sept. 15, 1922, Wash. Ured. 917; Port Discovery, Sept. 16, 1922, P. S. Simcoe, Wash. Ured. 889; Mt. Pleasant Rd., Sept. 19, 1922, Wash. Ured. 920; Port Angeles, Sept. 21, 1922, C. H. Johnson, Wash. Ured. 921; Joyce, Sept. 21, 1922, Wash. Ured. 923; Piedmont,

Sept. 22, 1922, Wash. Ured. 924; Seabeck, Sept. 26, 1922, Wash. Ured. 926; Lofall, Sept. 26, 1922, Wash. Ured. 927; Silverdale, Sept. 27, 1922, Wash. Ured. 928; Olalla, Sept. 28, 1922, Wash. Ured. 929; Gig Harbor, Oct. 20, 1922, C. H. Johnson, Wash. Ured. 894; Burley, Oct. 20, 1922, C. H. Johnson, Wash. Ured. 895; Glacier, Oct. 25, 1922, C. H. Johnson, Wash. Ured. 893; Bow, Oct. 30, 1922, C. H. Johnson, Wash. Ured. 912; Deming, Oct. 31, 1922, C. H. Johnson, Wash. Ured. 899; Noon, Oct. 31, 1922, C. H. Johnson, Wash. Ured. 900; Van Zandt, Nov. 6, 1922, E. Bethel, Wash. Ured. 904; Bellingham, Nov. 7, 1922, E. Bethel, Wash. Ured. 906; Sedro Woolley, Nov. 10, 1922, E. Bethel, Wash. Ured. 907.

*Ribes nigrum* L. Port Townsend, Oct., 1921, H. N. Putnam, Wash. Ured. 947; Sumas, Nov. 17, 1921, H. N. Putnam, Wash. Ured. 871; Mt. Vernon, Nov. 20, 1921, H. N. Putnam, Wash. Ured. 872; Everett, Nov., 1921, E. Bethel, Bur. Pl. Ind.; Edison, June 25, 1922, D. B. Leonard, Wash. Ured. 873; Sedro Woolley, June 27, 1922, R. M. Oltman, Bur. P. Ind.; Clear Lake, July 6, 1922, L. A. Huber, Bur. P. Ind.; Blaine, July 11, 1922, W. S. Smith, Bur. P. Ind.; Birch Bay, July 15, 1922, P. Young, Bur. P. Ind.; Deming, July 24, 1922, C. F. Lackey, Bur. P. Ind.; Bellingham, July 31, 1922, D. B. Leonard, Wash. Ured. 875; Oak Harbor, Aug. 4, 1922, H. N. Putnam, Wash. Ured. 876; Greenback, Aug. 4, 1922, H. N. Putnam, Wash. Ured. 877; Friday Harbor, Aug. 7, 1922, R. S. Sprague, Wash. Ured. 878; Shaw Island, Aug. 8, 1922, H. M. Walker, Bur. P. Ind.; Birch Bay, Aug. 9, 1922, C. H. Spiegelberg, Wash. Ured. 879; Licking, Aug. 10, 1922, H. N. Putnam, Bur. P. Ind.; Bellingham, Aug. 10, 1922, D. B. Leonard, Wash. Ured. 880; Marietta, Aug. 11, 1922, G. A. Huber, Wash. Ured. 881; Doe Bay, Aug. 11, 1922, H. M. Walker, Bur. P. Ind.; Olga, Aug. 11, 1922, H. M. Walker, Wash. Ured. 882; Ferndale, Aug. 12, 1922, G. A. Huber, Bur. P. Ind.; East Sound, Aug. 15, 1922, R. S. Sprague, Wash. Ured. 883; La Conner, Aug. 17, 1922, Moreland & Smith, Bur. P. Ind.; Arlington, Aug. 18, 1922, Rex Brown, Bur. P. Ind.; Nooksack, Aug. 21, 1922, M. M. Hess, Bur. P. Ind.; Mackay Harbor, Aug. 21, 1922, R. S. Sprague, Wash. Ured. 884; Cove, Aug. 22, 1922, W. S. Smith, Wash. Ured. 891; Oak Harbor, Aug. 22, 1922, H. N. Putnam, Wash. Ured. 885; Bay Center, Aug. 24, 1922, Wash. Ured. 930; Ilwaco, Aug. 25, 1922, Wash. Ured. 931; Oysterville, Aug. 25, 1922, Wash. Ured. 932; Oceanside, Aug. 25, 1922, Wash. Ured. 933; Rhodesia, Aug. 29, 1922, Wash. Ured. 934; Port Townsend, Sept. 9, 1922, Wash. Ured. 935; Shine, Sept. 11, 1922, Wash. Ured. 936; Woodman, Sept. 13, 1922, Wash. Ured. 937;

Chimacum, Sept. 15, 1922, Wash. Ured. 938; Sequim, Sept. 18, 1922, Wash. Ured. 939; Dungeness, Sept. 18, 1922, Wash. Ured. 940; Port Angeles, Sept. 21, 1922, Wash. Ured. 941; Seabeck, Sept. 25, 1922, Wash. Ured. 942; Port Gamble, Sept. 26, 1922, Wash. Ured. 943; Poulsbo, Sept. 27, 1922, Wash. Ured. 944; Suquamish, Sept. 27, 1922, Wash. Ured. 945; Keyport, Sept. 27, 1922, Wash. Ured. 946; Forks, Oct. 9, 1922, H. G. Bartow, Wash. Ured. 892; Belfair, Oct. 12, 1922, C. H. Johnson, Wash. Ured. 893; Aberdeen, Oct. 24, 1922, E. Bethel, Wash. Ured. 897; Chico, Nov. 16, 1922, H. G. Bartow, Wash. Ured. 909; Port Angeles, Nov. 23, 1922, C. H. Johnson, Wash. Ured. 910; Chesaw, Sept. 7, 1923, Root and Back, Bur. Pl. Ind., Blister Rust Control; Molson, Sept. 8, 1923, Root and Back, Bur. Pl. Ind., Blister Rust Control; Tonasket, Sept. 7, 1923, Root and Back, Bur. Pl. Ind. Blister Rust Control; Danville, Sept. 21, 1923, P. S. Simcoe, Bur. Pl. Ind. Blister Rust Control.

*Ribes divaricatum* Dougl. Sequim, Sept. 21, 1922, Wash. Ured. 922; Center, Nov. 15, 1922, P. S. Simcoe, Wash. Ured. 908.

*Ribes sanguineum* Pursh. Sequim, Nov. 25, 1922, P. S. Simcoe, Wash. Ured. 911.

*Ribes vulgare* Dougl. Doe Bay, Aug. 11, 1922, H. W. Walker, Bur. Pl. Ind.; Sequim, Oct. 23, 1922, H. G. Bartow, Bur. Pl. Ind.; Aberdeen, Nov. 1, 1922, W. S. Smith, Wash. Ured. 902; Port Gamble, Nov. 6, 1922, H. G. Bartow, Wash. Ured. 903; Chesaw, Sept. 8, 1923, Root and Back, Bur. Pl. Ind. Blister Rust Control.

### **Hyalopsora Magn.**

#### **12. Hyalopsora aspidiotus (Pk.) Magn.**

Ber. Deuts. Bot. Ges. 19:582, 1901; N. Am. Flora 7:112, 1907.

*Uredo aspidiotus* Pk. Ann. Rept. N. Y. State Mus. 24:88, 1872.

*Hyalopsora polypodii-dryopteridis* Magn. Hedwigia Beibl. 41:224, 1902.

On POLYPODIACEAE: II, III. Heteroecious. (0, I probably on Abies).

*Phcgopteris dryopteris* (L.) Fee. Chiquash Mts., Aug. 19, 1892, W. N. Suksdorf 354, Wash. Ured. 616; Newport, Feb. 28, 1916, J. R. Weir 63, Arth. Herb.; Sol Duc Hot Springs, July 13, 1920, J. S. Boyce 624, Wash. Ured. 2853.

The genus *Hyalopsora* has been reported to have two sets of spores that resemble urediniospores, both being borne singly on pedicels. Arthur in N. Am. Flora regarded these as aecio- and urediniospores, while some other authors referred to them as two kinds of urediniospores, the aecia being wanting or occurring on another host.

Recent investigations would indicate that this genus and also *Uredinopsis* are heteroecious, the aecial stage coming on some species of *Abies*.

**13. *Hyalopsora laeviuscula* (D. & H.) Arth.**

N. Am. Flora 7:113, 1907.

*Uredo laeviuscula* Dietel & Holway, *Erythea* 2:217, 1894.

On POLYPODIACEAE: II, III. Heteroecious (0, I probably on *Abies*).

*Polypodium occidentale* (Hook.) Maxon. Klickitat River, May 8, 1886, W. N. Suksdorf 237, Wash. Ured. 563; Bingen, May 12, 1904, W. N. Suksdorf 973, Wash. Ured. 738.

**14. *Hyalopsora polypodii* (DC.) Magn.**

Ber. Deuts. Bot. Ges. 19:582, 1901; N. Am. Flora 7:112, 1907.

*Uredo polypodii* DC. Fl. Fr. 6:81, 1815.

On POLYPODIACEAE: II, III. Heteroecious.

*Filix fragilis* (L.) Underw. Bingen, May 12, 1904, W. N. Suksdorf 974, Wash. Ured. 739; Fort George Wright, May 27, 1920, W. E. Flowers 6412, Wash. Ured. 1259; Mt. Rainier, Aug. 13, 1920, A. Frank, 117, Wash. Ured. 423.

*Woodsia oregana* D. C. Eaton. Spokane, May 21, 1912, W. E. Flowers 6411, Wash. Ured. 1140; Locke, Aug. 30, 1915, W. E. Flowers 6112, Wash. Ured. 2549.

**Melampsora Cast.**

**15. *Melampsora abietis-canadensis* (Farl.) Ludwig.**

Phytopath. 5:279, 1915.

*Caeoma abietis-canadensis* Farl. Proc. Am. Acad. 20:323, 1885.

*Peridermium fructigenum* Arth. Bull. Torrey Club 37:578, 1910.

*Caeoma tsugae* Spaulding, Sci. n. s. 33:194, Hyponym, 1911.

On SALICACEAE: II, III (0, I on *Tsuga canadensis* (L.) Carr.)

*Populus alba* L. Clarkston, May 6, 1915, B. F. Dana, Herb. W.S. C. 91, Wash. Ured. 2714.

**16. *Melampsora albertensis* Arth.**

Bull. Torrey Club 33:517, 1906; N. Am. Flora 7:665, 1924.

*Caeoma occidentalis* Arth. Bull. Torrey Club 34:591, 1907.

*Uredo albertensis* Arth. N. Am. Flora 7:101, 1907.

On PINACEAE: 0, I. Heteroecious.

*Pseudotsuga mucronata* (Raf.) Suds. Longmire Springs, Mt. Rainier, Aug., 1913, C. Von Tubeuf (Nat. Zeit. f. Forst und Landw. 12:19, 1914) Arth. Herb.; Spokane, July 10, 1914, W. E. Flowers

6063, Wash. Ured. 2542; Locke, Aug. 25, 1915, W. E. Flowers 6479, Wash. Ured. 1147; Lake Chelan, Aug. 22, 1916, J. R. Weir, Barth. N. Am. Ured. 1721.

On SALICACEAE: II, III.

*Populus tremuloides* Michx. Spokane, Sept. 10, 1910, W. E. Flowers 6327, Wash. Ured. 2593; Bellingham, June, 1913, J. R. Weir 33, Arth. Herb.; Locke, Aug. 25, 1915, W. E. Flowers 6378, Wash. Ured. 1146; Pullman, Sept. 2, 1920, B. F. Dana, Herb. W.S.C. Wash. Ured. 1160.

**17. *Melampsora humboldtiana* Speg.**

An. Mus. Nac. Buenos Aires 23:28, 1912; N. Am. Flora 7:668, 1924.  
*Melampsora americana* Arth. Bull. Torrey Club, 47:465, 1920.

On PINACEAE: 0, I. Heteroecious.

*Abies grandis* Lindl. Sol Duc Hot Springs, July 14, 1921, J. R. Weir, Arth. Herb.

*Abies lasiocarpa* (Hook.) Nutt. Seattle, 1906, Bonser 35, Arth. Herb.

On SALICACEAE: II, III.

*Salix bebbiana* Sarg. Metaline Falls, J. R. Weir 10, Arth. Herb.

*Salix* sp. Tumwater, Sept. 24, 1919, Wash. Ured. 323; Parker Lake, June, 1920, W. E. Flowers 6408, Wash. Ured. 1251.

**18. *Melampsora bigelowii* Thüm.**

Mitth. Forstl. Vers. Oest. 2:37, 1879.  
*Melampsora paradoxa* Diet. & Holw. Hedw. Beibl. 40:32, 1901.  
*Uredo bigelowii* (Thüm.) Arth. Result. Sci. Congr. Bot. Vienne 338, 1906;  
N. Am. Flora 7:100, 1907.

On PINACEAE: 0, I. Heteroecious.

*Larix occidentalis* Nutt. Locke, Sept. 16, 1916, W. E. Flowers 6380, Wash. Ured. 1159.

On SALICACEAE: II, III.

*Salix bebbiana* Sarg. Pullman, June 29, 1898, C. V. Piper 511, Wash. Ured. 2924; Locke, June 20, 1915, W. E. Flowers 6174, Wash. Ured. 2569; Spokane, June 11, 1919, W. E. Flowers 6237, Wash. Ured. 2577.

*Salix cordata* Muhl. Pullman, June 29, 1898, C. V. Piper 512, Herb. W.S.C.; Waitsburg, Oct. 15, 1900, R. M. Horner 1495, Herb. W.S.C.

*Salix fluviatilis* Nutt. Pullman, Sept. 23, 1893, C. V. Piper 503, Wash. Ured. 2888; Waitsburg, Aug. 27, 1897, R. M. Horner, Wash. Ured. 2922.

*Salix hookeriana* Barr. Hoquiam July 2, 1920, C. R. Stillinger 760, Wash. Ured. 1090.

*Salix lasiandra lyallii* Sarg. Seattle, Oct. 16, 1891, A. M. Parker 25, Herb. W.S.C., also Sept. 1892, C. V. Piper 505, Herb. W.S.C., Wash. Ured. 1294; Pullman, Sept. 23, C. V. Piper 504, Wash. Ured. 2887; Bainbridge Island, Aug. 4, 1909, Mr. & Mrs. E. Bartholomew, Fungi Columb. 3141, Herb. W.S.C.; Spokane, April 13, 1912, W. E. Flowers, 6124, Wash. Ured. 2555.

*Salix myrtilloides* L. Seattle, June, 1892, C. V. Piper, Herb. W. S.C. Wash. Ured. 1295.

*Salix piperi* Bebb. Wenatchee, July 15, 1912, E. Bartholomew, Fungi Columb. 4432, Herb. W.S.C.

*Salix scouleriana* Barr. Seattle, Oct. 1891, C. V. Piper 24, Herb. W.S.C., Wash. Ured. 1293; Pullman, July 19, 1899, R. M. Horner 1289, Herb. W.S.C.; Bainbridge Island, Aug. 10, 1909, E. Bartholomew, Fungi Columb. 3142, Herb. W.S.C.

*Salix sitchensis* Sans. Olympia, Sept. 12, 1912, E. Bartholomew, Fungi Columb. 4433, Herb. W.S.C.

*Salix* sp. Bingen, Oct. 13, 1894, W. N. Suksdorf 411, Wash. Ured. 661; Mt. Adams, Sept. 5, 1900, W. N. Suksdorf 589, Wash. Ured. 704; Spokane, Sept. 10, 1905, W. E. Flowers 6102, Wash. Ured. 1148; Nespelem, Sept. 20, 1915, B. F. Dana, Herb. W.S.C. 377, Wash. Ured. 1164; Pullman, July 6, 1916, B. F. Dana, Herb. W. S. C. 347, Wash. Ured. 1163; Seattle, Oct. 3, 1919, Wash. Ured. 321; Ellensburg, Sept. 18, 1920, G. L. Zundel, Wash. Ured. 1281; Puyallup, July 17, 1921, A. Frank 128, Wash. Ured. 413.

### 19. *Melampsora confluens* (Pers.) Jackson.

Brooklyn Bot. Gard. Mem. 1:210. 1918.

*Uredo confluens* Pers. Obs. Myc. 1:98, 1796; N. Am. Flora 7:99, 1907; 7:667, 1924.

On SAXIFRAGACEAE: 0, I. Heteroecious.

*Ribes bracteosum* Dougl. Kerriston, July 10, 1920. F. G. Renner, Wash. Ured. 164; Stampede, July 10, 1920, F. G. Renner, Wash. Ured. 165; Glacier, May 22, 1922, H. N. Putnam, Wash. Ured. 953.

*Ribes divaricatum* Dougl. Silverton, July 5, 1920, C. R. Stillinger 731, Wash. Ured. 35; Glacier, May 22, 1922, H. N. Putnam, Wash. Ured. 954.

*Ribes lacustre* (Pers.) Poir. Cascade Mts., Aug. 10, 1893. J. A. Allen. Arth. Herb.; Glacier, May 22, 1922, H. N. Putnam, Wash. Ured. 955.

## On SALICACEAE: II, III.

*Salix bebbiana* Sargent. Locke, Sept. 13, 1915, W. E. Flowers 6362. Wash. Ured. 1149.

*Salix cordata* Muhl. Spokane, Sept. 16, 1912, W. E. Flowers 6367, Wash. Ured. 1150.

*Salix geyeriana* Anderss. Hartford, July 9, 1920, C. R. Stillinger, Arth. Herb., Wash. Ured. 845.

*Salix scouleriana* Barr. Hoquiam, July 2, 1920, C. R. Stillinger 1049, Arth. Herb.; Glacier, July 7, 1920, C. R. Stillinger 753, Wash. Ured. 1083; Hartford, July 9, 1920, C. R. Stillinger 742; Kirkland, July 10, 1920, C. R. Stillinger 723, Wash. Ured. 828; Monte Cristo, Aug. 8, 1920, F. G. Renner, Arth. Herb.

*Salix sitchensis* Sans. Bothell, July 25, 1920, C. R. Stillinger 848, Arth. Herb.

*Salix subcoeruleae* Piper. Montborne, Aug. 17, 1920, W. E. Morgan, Arth. Herb.

*Salix* sp. White Salmon River, Sept. 12, 1884, W. N. Suksdorf 159, Wash. Ured. 529; Chelan, Aug. 27, 1916, J. R. Weir 11224, Arth. Herb.; Spokane, Sept., 1919, J. R. Weir 11168, Arth. Herb.; Silverton, July 5, 1920, G. B. Posey & C. R. Stillinger 730, Wash. Ured. 842.

**20. *Melampsora lini* (Pers.) Desmaz.**

Pl. Crypt. (Fasc. 41) 2049, 1850.

*Uredo miniata lini* Pers. Syn. Fungi 216. 1801.

*Uredo lini* Schum. Enum. Pl. Saell. 2:230. 1803; N. Am. Flora 7:101. 1907.

## On LINACEAE: 0, I, II, III. Autoecious.

*Linum lewisii* Pursh. Pullman, July 14, 1899, R. M. Horner 1193, Herb. W.S.C.; Connell, June 30, 1923, G. L. Zundel, Wash. Ured. 1151.

**21. *Melampsora occidentalis* Jackson.**

Phytopath. 7:354, 1917; N. Am. Flora 7:666, 1924.

On SALICACEAE: II, III. Heteroecious (0, I probably on *Larix*).

*Populus angustifolia* James. Seattle, 1906, Bonner 13. Comm. by J. G. Hambleton, Arth. Herb.; Puyallup, Oct., 1922, A. Frank 239, Wash. Ured. 432.

*Populus balsamifera* L. Bremerton, Sept. 23, 1912, E. Bartholomew, Barth. Fungi Columb. 4434, Barth. N. Am. Ured. 806.

*Populus trichocarpa* T. & G. Seattle, Oct. 8, 1892, A. M. Parker, also Oct. 3, 1913. Wash. Ured. 310; Bingen, Nov. 15, 1894. W. N. Suksdorf 497, Wash. Ured. 677; Waitsburg, Oct. 15, 1899, R. M.



Horner 1414, Herb. W.S.C.; Puyallup, Aug. 23, 1909. E. Bartholomew, Barth. Fungi Columb. 4143, also Oct. 20, 1916, A. Frank, Wash. Ured. 431; Spokane, Aug. 12, 1912, W. E. Flowers 6325, Wash. Ured. 2591; Longmire, Mt. Rainier (Recorded in Nat. Zeit. Forst. Landw. 12:90, 1914) C. Van Tubeuf; Locke, Aug. 20, 1915, W. E. Flowers 6421, Wash. Ured. 1154; Langley, Sept., 1919, J. M. Grant, Wash. Ured. 304; Index, Aug. 17, 1920, G. Sartoris, Wash. Ured. 172; Palouse, Sept. 15, 1920, G. B. Posey and C. R. Stillinger 774, Wash. Ured. 1091; Stevenson, Sept. 17, 1920, J. G. Boyce 671, Wash. Ured. 2858; Snoqualmie Falls, Nov. 10, 1923, Wash. Ured. 1272.

*Populus* sp. Darrington, Aug. 8, 1920, C. R. Stillinger, Wash. Ured. 1094.

There are three species of *Melampsora* found on *Populus* in the state of Washington: *M. albertensis* Arth. and *M. abietis-canadensis* (Farl.) Ludwig are apparently confined to *P. tremuloides* and *P. alba* respectively. *M. occidentalis* Jackson occurs on various other species of *Populus* and has been generally referred to *M. medusae* Thüm., but Jackson has clearly shown that it does not belong there (Phytopath. 7:353, 1917). "This species differs from all other species of *Melampsora* on *Populus* in the large size of the urediniospores which are only slightly flattened and are evenly verrucose-echinulate. The teliospores are much longer than those of *M. medusae* and are thickened at the apex. The character of the telial sori suggests that this species may be closely allied to *M. albertensis*. The sori are much larger as are also both uredinio- and teliospores." (Jackson).

### ***Melampsorella* Schröter**

#### **22. *Melampsorella elatina* (A. & S.) Arth.**

N. Am. Flora 7:111. 1907.

*Aecidium elatinum* Alb. & Schw. Consp. Fung. 121. 1805.

*Melampsorella cerastii* (Pers.) Schroet. Krypt. Flor. Schles. 3:366, 1887.

On PINACEAE: 0, I. Heteroecious.

*Abies amabilis* (Loud.) Forb. Mt. Rainier, (without a date), C. J. Kroebel, Arth. Herb.

*Abies grandis* Lindl. Mt. Vernon, May, 1922, L. Sundquist, Wash. Ured. 977.

*Abies lasiocarpa* (Hook.) Nutt. Lake Chelan, Aug. 29, 1916, J. R. Weir, Barth. N. Am. Ured. 2022, Arth. Herb.; Locke, Aug. 10, 1917, W. E. Flowers 6061, Wash. Ured. 2540.

## On CARYOPHYLLACEAE: II, III.

*Cerastium viscosum* L. Joyce, June 27, 1922. Wash. Ured. 984; Elwha, June 28, 1922, Wash. Ured. 986.

*Stellaria borealis* Bigel. Falcon Valley, July 31, 1885, W. N. Suksdorf 209, Wash. Ured. 556; Sedro-Woolley, Oct. 11, 1922, E. Bethel, Wash. Ured. 1165.

*Stellaria media* (L.) Cyr. Waitsburg, Mar. 31, 1900, R. M. Horner 1419, Herb. W.S.C.

This rust is probably more widely spread throughout the state than the above references would indicate. "It is remarkable in that both stages develop from a perennial mycelium. The aecial stage forms large or small witches' brooms on the branches of various species of *Abies*, each leaf of which bears the conspicuous aecia in two rows on the under surface of the leaves." (Jackson).

**Melampsoridium Klebahn****23. Melampsoridium betulae (Schum.) Arth.**

N. Am. Flora 7:110, 1907.

*Melampsora betulina* Tul. Ann. Sci. Nat. IV. 2:97, 1854.

*Aecidium laricis* Kleb. Zeits. Pflanzenkr. 9:18, 1899.

*Peridermium laricis* Arth. & Kern, Bull. Torrey Club 33:436, 1906.

On BETULACEAE: II, III. Heteroecious (0, I on *Larix*).

*Betula glandulosa* Michx. Falcon Valley, W. N. Suksdorf 15, Wash. Ured 502.

**Milesia White****24. Milesia polystichii Wineland.**

Brooklyn Bot. Gard. Mem. 1:214, 1918.

On POLYPODIACEAE: II. Heteroecious (0, I unknown).

*Polystichum munitum* (Kauf.) Presl. Lake Chelan, Aug. 25, 1916, J. R. Weir, 7534, Arth. Herb.; Sol Duc, July 14, 1921, J. R. Weir 19903, Arth. Herb.

There is some evidence that *Peridermium rugosum* Jackson may be the aecial stage of this rust. At least it might be worth while testing it by cultures.

Although only the uredinia of this rust have been found there seems little doubt but that it belongs to the genus *Milesia* (*Milesina* Magnus.) It is therefore placed here rather than in the genus *Uredo*, among the imperfect rusts.

**Pucciniastrum** Otth.**25. Pucciniastrum goodyerae** (Tranz.) Arth.

N. Am. Flora 7:105, 1907.

*Uredo goodyerae* Tranz. Trudi S. Peterb. Obshch. Est. Otd. Bot. 23:28, 1893.

On ORCHIDACEAE: II, III (0, I unknown).

*Peramium decipiens* (Hook.) Piper. Bingen, July 2, 1896, E. W. D. Holway, Arth. Herb., also W. N. Suksdorf 529, Wash. Ured. 678, also Nov. 5, 1898, W. N. Suksdorf 988, Wash. Ured. 748; Peter's Prairie, Sept. 16, 1902, W. N. Suksdorf 797, Wash. Ured. 727; Locke, June 11, 1915, W. E. Flowers 6173, Wash. Ured. 2568; Sol Duc Hot Springs, July 14, 1920, J. R. Weir and J. S. Boyce 618, Wash. Ured. 2852.

**26. Pucciniastrum myrtilli** (Schum.) Arth.

Result. Sci. Congr. Bot. Vienne 337, 1906; N. Am. Flora 7:109, 1907.

*Aecidium ? myrtilli* Schum. Enum. Pl. Saccl. 2:227, 1803.

*Pucciniastrum vacciniarum* (DC) Dietel, in E. & P. Nat. Pfl. 1<sup>1\*\*</sup>:47, 1897.

On VACCINIACEAE: II, III (0, I unknown).

*Vaccinium caespitosum* Michx. Falcon Valley, July 30, 1885, W. N. Suksdorf 202, Arth. Herb., Wash. Ured. 552; Chiquash Mts., Aug. 28, 1895, W. N. Suksdorf 1083, Wash. Ured. 780; Pullman, July 28, 1894, C. V. Piper 276, Wash. Ured. 2905; Locke, Sept. 20, 1915, W. E. Flowers 6334, Wash. Ured. 2596.

*Vaccinium membranaceum* Dougl. Skamania Co., Aug. 12, 1886, W. N. Suksdorf 335, Wash. Ured. 610; Paradise Valley, Mt. Rainier Aug. 24, 1901, E. D. W. Holway, N. Am. Ured. 1481, Arth. Herb.; Bellingham, June, 1913, J. R. Weir 81, Arth. Herb.; Locke, Sept. 20, 1915, W. E. Flowers 6334, Wash. Ured. 2596; Chelan, Aug. 26, 1916, J. R. Weir, Arth. Herb. Fungi Columb. 5083; Mt. Baldy, Aug. 11, 1923, A. J. Seltzer, Wash. Ured. 1212.

*Vaccinium parvifolium* Smith. Duckabush River, Aug. 12, 1914, E. Bartholomew, N. Am. Ured. 1182.

**27. Pucciniastrum pustulatum** (Pers.) Dietel.

E. & P. Nat. Pfl. 1<sup>1\*\*</sup>:47, 1897; N. Am. Flora 7:107, 1907.

*Pucciniastrum epilobii* Otth. Mitth. Nat. Ges. Bern 1861:72, 1861.

*Pucciniastrum abieti-chamaenerii* Kleb. Jahrb. Wiss. Bot. 34:387, 1900.

On PINACEAE: 0, I. Heteroecious.

*Abies amabilis* (Loud). Forb. Fairfax, J. S. Boyce 864, Aug. 20, 1921, Arth. Herb., Wash. Ured. 1333.

*Abies grandis* Lindl. Mt. Baker, Oct. 31, 1903, W. N. Suksdorf

965, Arth. Herb.; Locke, Aug. 15, 1917, W. E. Flowers 6040, Wash. Ured. 2537.

*Abies lasiocarpa* (Hook.) Nutt. Chiquash Mt., Aug. 11, 1886, W. N. Suksdorf 296, Wash. Ured. 1177; Lake Chelan, 1914, J. R. Weir 10891, Arth. Herb.; Lock, Aug. 15, 1917, W. E. Flowers 6370, Wash. Ured. 1125.

On ONAGRACEAE: II, III.

*Epilobium adenocaulon* Haussk. Bingen, Apr. 3, 1894, W. N. Suksdorf 396, Wash. Ured. 649; Pullman, July 28, 1899, R. M. Horner 1202, Herb. W.S.C.; Bainbridge Island, Aug. 4, 1909, Mr. and Mrs. E. Bartholomew, Arth. Herb.; Bremerton, Sept. 18, 1912, E. Bartholomew, Arth. Herb.; Spokane, Aug. 10, 1913, W. E. Flowers 6131, Wash. Ured. 2559; Kirkland, July 10, 1920, C. R. Stillinger 709, Wash. Ured. 817; Yarrow, Oct. 1, 1920, Grace Howard, Wash. Ured. 121; Houghton, Nov. 12, 1921, Wash. Ured. 237.

*Epilobium angustifolium* L. Seattle, Sept., 1892, C. V. Piper 219, Herb. W.S.C., Wash. Ured. 1292; Mt. Adams, Aug. 6, 1903, W. N. Suksdorf 968, Wash. Ured. 734; Indian Canyon, July 10, 1910, W. E. Flowers 6116, Wash. Ured. 2550; Bremerton, July 24, 1912, E. Bartholomew, Barth. N. Am. Ured 1897, Arth. Herb.; Chimacum, July 26, 1915, D. C. George, Herb. W.S.C. 170, Wash. Ured. 2730; Locke, Aug. 15, 1917, W. E. Flowers 6335, Wash. Ured. 2597; Silvertown, July 7, 1920, C. R. Stillinger 630, Wash. Ured. 807; Pendle, Aug. 3, 1920, J. S. Boyce 680, Wash. Ured. 2859; Carson, Sept. 16, 1920, J. S. Boyce 683, Wash. Ured. 2860; Pullman, Sept. 30, 1920, Herb. W.S.C. 739, Wash. Ured. 1124; Snoqualmie Falls, Oct. 24, 1920, Wash. Ured. 187; Yeomalt, Oct. 7, 1921, Wash. Ured. 214; Quilcene, Sept. 19, 1922, Wash. Ured. 1055; Port Townsend, Sept. 20, 1922, Wash. Ured. 1054; Port Angeles, Sept. 23, 1922, Wash. Ured. 1056; Crescent Lake, Sept. 24, 1922, Wash. Ured. 1057; Seabeck, Sept. 25, 1922, Wash. Ured. 1058.

*Epilobium clavatum* Trelease. Mt. Adams, July 5, 1900, W. N. Suksdorf 584, Wash. Ured. 699.

*Epilobium paniculatum* Nutt. Yarrow, Oct. 1, 1921, Grace Howard, Wash. Ured. 213.

*Epilobium* sp. Bingen, June 23, 1894, W. N. Suksdorf 396, Wash. Ured. 648.

The rust that occurs on *Epilobium angustifolium* has been shown both in Europe (Klebahn, Die Wirtsw. Rostpilze 393. 1904) and in America (Fraser, Mycol. 4:176, 1912 and Weir and Hubert, Phytopath. 6:373, 1916, and 7:109, 1917) to have its aecia on species of

*Abies*. Since no successful culture work has been conducted on any other species, the one occurring on *E. angustifolium* is, by some authors, separated from *P. pustulatum* under the name *P. abieti-chamaenerii* Kleb. For the purpose of this list it seems best to make the above disposition.

**28. *Pucciniastrum pyrolae* (Pers.) Dietel.**

E. & P. Nat. Pfl. 1<sup>1</sup>\*\*:47, 1897; N. Am. Flora 7:108, 1907.

*Aecidium pyrolae* Pers. Gmel. Syst. Nat. 2:1473, 1791.

*Uredo chimaphilae* Peck, Ann. Rep. N. Y. State Mus. 46:33, 1893.

On PYROLACEAE: II, III (0, I unknown).

*Chimaphila umbellata* (L.) Nutt. Chiquash Mts., July 20, 1894, W. N. Suksdorf 452, Wash. Ured. 665; Mt. Adams, July 27, 1895, W. N. Suksdorf 1082, Wash. Ured. 779.

*Pyrola secunda* L. Mt. Adams, Aug. 17, 1885, W. N. Suksdorf 213, Arth. Herb., Wash. Ured. 560; Pullman, June 30, 1915, F. D. Heald and D. C. George, Herb. W.S.C. 56.

**29. *Pucciniastrum sparsum* (Wint.) Ed. Fisch.**

Beitr. Krypt. Schweiz. 2<sup>a</sup>:469, 1904; N. Am. Flora 7:108, 1907.

*Melampsora sparsa* Wint. in Rab. Krypt. Fl. 1<sup>1</sup>:245, 1881.

*Uredo arbuti* Dietel & Holway, Bot. Gaz. 18:256, 1893.

*Pucciniastrum arbuti* Dietel & Holway, in E. & P. Nat. Pfl. 1<sup>1</sup>\*\*:47, 1897.

*Uredo copelandii* Sydow, Ann. Myc. 2:31, 1904.

On ERICACEAE: II, III (0, I unknown).

*Arbutus menziesii* Pursh. Bainbridge Island, Aug. 17, 1909, E. Bartholomew 3181, Arth. Herb.; Bremerton, Sept. 18, 1912, E. Bartholomew, Arth. Herb.; Seattle, Oct. 15, 1919, Wash. Ured. 335, also Sept. 17, 1920, W. E. Flowers 6333, Wash. Ured. 1175; Charleston, May 22, 1921, Grace Howard, Wash. Ured. 197; Winslow, June 15, 1921, Wash. Ured. 1176.

*Arctostaphylos columbiana* Piper. Olympic Mts., Sept. 17, 1920, W. E. Flowers 6371, Wash. Ured. 1128.

***Uredinopsis* Magn.**

**30. *Uredinopsis atkinsonii* Magn.**

Hedwigia 43:123. Mar. 1904; N. Am. Flora 7:117, 1907.

*Peridermium balsameum* Peck, Rept. N. Y. State Mus. 27:104, 1875.

*Uredinopsis copelandii* Sydow, Ann. Myc. 2:34, Feb. 1904; N. Am. Flora 7:116, 1907.

On PINACEAE: 0, I. Heteroecious.

*Abies grandis* Lindl. Mt. Adams, Oct. 31, 1903, W. N. Suksdorf 965, Wash. Ured. 731; Silverton, July 8, 1920, C. R. Stillinger

739, Wash. Ured. 841; Elbe, July 27, 1921, J. S. Boyce 862, Arth. Herb., Wash. Ured. 1332.

*Abies lasiocarpa* (Hook.) Nutt. Chiquash Mts., Aug. 11, 1886, W. N. Suksdorf 296, Wash. Ured. 1177.

*Abies nobilis* Lindl. Cascade Mts., Snohomish Co., Aug., 1915, H. Schmitz, Arth. Herb.; Elwha Valley, Clallam Co., Aug., 1919, A. Curtis, Wash. Ured. 329.

On POLYPODIACEAE: II, III.

*Athyrium cyclosorum* Rupr. Manette, Aug. 17, 1912, E. Bartholomew, Barth. Fungi Columb. 4491, Arth. Herb.; Bellingham, June, 1913, J. R. Weir 43, Arth. Herb.; Locke, Aug. 30, 1915, W. E. Flowers 6107, Wash. Ured. 1134; Lake Chelan, Aug. 26, 1916, J. R. Weir, 14439, Arth. Herb.; Silverton, July 6, 1920, C. R. Stillinger 533, Wash. Ured. 804.

The different species belonging to the genus *Uredinopsis* seem to be separated on rather slight morphological characters. This is particularly true in connection with *U. copelandii* Sydow and *U. atkinsonii* Magn. and no attempt has been made to separate them.

31. *Uredinopsis pteridis* Diet. & Holw.

Ber. Deuts. Bot. Ges. 13:331, 1895; N. Am. Flora 7:116, 1907.

*Accidium pseudo-balsameum* Diet. & Holw., Erythea 7:98, 1899.

*Peridermium pseudo-balsameum* Arth. & Kern., Bull. Torrey Club 33:430, 1906.

On PINACEAE: 0, I. Heteroecious.

*Abies grandis* Lindl. Falcon Valley, Aug. 3, 1907, W. N. Suksdorf 1057, Wash. Ured. 756; Locke, Aug. 5, 1915, W. E. Flowers 6132, Wash. Ured. 1132; Lucerne, Aug. 25, 1916, J. R. Weir, Barth. N. Am. Ured. 1619, Arth. Herb.; Castle Pt., June 19, 1919, L. Hartge, Wash. Ured. 1013; Friday Harbor, Aug., 1922, L. Hartge, Wash. Ured. 1012.

On POLYPODIACEAE: II, III.

*Pteridium aquilinum pubescens* Und. Mt. Rainier, Aug. 27, 1901, E. W. D. Holway, Arth. Herb.; Port Orchard, July 23, 1912, E. Bartholomew, Barth. N. Am. Ured. 1383, Barth. Fungi Columb. 4492, Arth. Herb.; Locke, Aug. 15, 1915, W. E. Flowers 6133, Wash. Ured. 1133; Piedmont, July 15, 1920, J. S. Boyce 601, Wash. Ured. 2851.

It is worthy of note that the aecial stage of all recorded species of *Uredinopsis* occurs on *Abies*.

**PUCCINIACEAE**

Teliospores stalked, usually free but sometimes fascicled, wall firm or with an outer gelatinous layer, each spore composed of one or more cells arranged in rows or groups; basidiospores formed on a promycelium or external basidium. Aecia with or without peridia; urediniospores borne singly on pedicels.

A. Teliospores of one or two cells.

B. Teliospores one-celled, borne singly on pedicels.

C. Pycnia subcuticular, ostiolar filaments wanting; teliospores flattened above and below; life cycle 0, II, III.

PILEOLARIA (p. 306).

CC. Pycnia subepidermal, deep-seated with protruding ostiolar filaments; only one species with the life cycle 0, II, III reported from Washington.

UROMYCES (p. 361).

BB. Teliospores of two cells.

D. Teliospores embedded in gelatine, mostly on Gymnosperms, urediniospores usually wanting. GYMNOSPORANGIUM (p. 299).

DD. Teliospores free, usually on Angiosperms.

E. Teliospores with a more or less evident gelatinous layer, pores more than one placed laterally. UROPYXIS (p. 373).

EE. Teliospores without gelatinous layer, with one apical pore in each cell.

F. Aecia with peridia; pycnia subepidermal.

PUCCINIA (p. 306).

FF. Aecia without peridia; pycnia subcuticular.

GYMNOCONIA (p. 299).

AA. Teliospores of more than two cells, occasionally with only two.

G. Teliospores two to several cells in series. PIIRAGMIDIUM (p. 302).

GG. Teliospores with three radiating cells; two pores in each cell.

NYSSOPSORA (p. 302).

**Gymnoconia Lagerh.****32. *Gymnoconia interstitialis* (Schlecht.) Lagerh.**

Tromsø Mus. Aarsh. 16:140, 1894; N. Am. Flora 7:180, 1912.  
*Cacoma (Uredo) interstitialis* Schlecht. Horae Phys. Berol. 96. 1820.  
*Cacoma nitens* Burrill, Bull. Ill. Lab. Nat. Hist. 2:220. 1885.

On ROSACEAE: O, I, III. Autoecious.

*Rubus macropetalus* Dougl. Monroe, July, 1921, Wash. Ured. 286; Puyallup, July 24, 1921, A. Frank, Wash. Ured. 414.

*Rubus nigrobaccus* Bailey. Spokane, June 28, 1895, C. V. Piper, Herb. W.S.C., Wash. Ured. 1288; Almonta, 1895, G. H. Watt, Herb. W.S.C.; Monroe, A. Frank D136.

*Rubus strigosus* Michx. Everett, May 17, 1915, J. H. Brislaw, Wash. Ured. 74; Locke, May 30, 1915, W. E. Flowers 6320, Wash. Ured. 2586.

According to Kunkel's investigation on this rust there are in North America two rusts on *Rubus* both of which have been commonly referred to *Gymnoconia interstitialis* or *Cacoma nitens* (Bull. Torrey Club 43:559-569, 1916). One of these is a short-cycled form which Arthur has named *Kunkelia nitens* (Bot. Gaz. 63:504, 1917).

It is probable that the rust found in Washington has a short cycle and therefore belongs to the latter species but it seems to suit the purposes of the present list best to retain the old name.

**Gymnosporangium Hedw. f.****33. *Gymnosporangium betheli* Kern**

Bull. Torrey Club 34:459, 1907; N. Am. Flora 7:204, 1912.  
*Rocstelia betheli* Kern Bull. Torrey Club 34:461, 1907.

On ROSACEAE: O, I. Heteroecious.

*Crataegus douglasii* Lindl. Spokane, Aug. 28, 1898, C. V. Piper 549, Arth. Herb., Wash. Ured. 1232; Republic, Sept. 14, 1923, G. L. Zundel, Wash. Ured. 1225.



## On PINACEAE: III.

*Juniperus scopulorum* Sarg. Spokane, July 2, 1896, C. V. Piper 439, Wash. Ured. 1233; also Aug. 5, 1917, C. H. Shattuck, Arth. Herb.; Walla Walla, June 1, 1920, J. R. Weir 4570, Arth. Herb.; Friday Harbor, July 19, 1922, L. Hartge, Wash. Ured. 1282.

The telia have been found on *J. occidentalis* in Oregon. The species seems to be limited to the Pacific Northwest.

**34. *Gymnosporangium juniperinum* (L.) Mart.**

Fl. Crypt. Erlang. 333. 1817; N. Am. Flora 7:199, 1912.  
*Tremella juniperina* L. Sp. Pl. 1157, 1753.

On ROSACEAE: 0, I (III on *Juniperus*).

*Pyrus occidentalis* Wats. Lake Keechelus, Sept., 1915, Arth. Herb.

*Pyrus sitchensis* (Roem.) Piper. Skamania Co., Sept. 1, 1893, W. N. Suksdorf 255, Wash. Ured. 579, Arth. Herb.; Locke, Aug. 21, 1915, W. E. Flowers 6406, Wash. Ured. 1250.

*Pyrus* sp. Mt. Adams, Sept. 3, 1900, W. N. Suksdorf.

"This species is known in America only from the Rocky and Cascade Mountains of the United States and Canada." Jackson.

**35. *Gymnosporangium juvenescens* Kern**

Bull. N. Y. Bot. Gard. 7:448, 1911; N. Am. Flora 7:193, 1912.

On ROSACEAE: 0, I (III on *Juniperus*).

*Amelanchier alnifolia* Nutt. Spokane, Sept. 20, 1913, W. E. Flowers 6319, Wash. Ured. 2585; also Sept., 1916, J. R. Weir 11216, Arth. Herb.; Chelan, Aug., 1916, J. R. Weir 11170, Arth. Herb.

This species causes witches' brooms on the telial host, resembling somewhat those produced by *G. nidus-avis* Thax. in the eastern United States.

**36. *Gymnosporangium koreaense* (P. Henn.) Jackson**

Jour. Agr. Research 5:1006, 1916.  
*Roestelia koreaensis* P. Henn. in Warburg, Monsumia 1:5, 1899.  
*Gymnosporangium asiaticum* Miyabe, Bot. Mag. Tokio 17:34, 1903. (Hyponym.)  
*Gymnosporangium haraeianum* Syd. Am. Myc. 10:405, 1912.  
*Gymnosporangium chinense* Long. Jour. Agr. Research 1:353, 1914.

## On PINACEAE: III (0, I on Rosaceae).

*Juniperus chinensis* L. Seattle, May 19, 1915, Wash. Ured. 334.

This species was found on shrubs imported from Japan. In Oregon, Jackson has grown it on *Pyrus sinensis* and *Cydonia vulgaris*, producing aecia.

**37. *Gymnosporangium nelsoni* Arth.**

Bull. Torrey Club 28:665, 1901; N. Am. Flora 7:207, 1912.  
*Roestelia nelsoni* Arth. Bull. Torrey Club 28:665, 1901.  
*Aecidium nelsoni* Farl. Bibl. Index 1:68, 1905.  
*Gymnosporangium durum* Kern Bull. Torrey Club 34:460, 1907.

On ROSACEAE: 0, I (III on *Juniperus*).

*Pyrus diversifolia* Bong. Tulalip, Aug. 21, 1920, Wash. Ured. 291; Marysville, Aug. 21, 1921, Wash. Ured. 173.

*Pyrus occidentalis* S. Wats. Mt. Adams, 1896, W. N. Suksdorf 1084, Wash. Ured. 781.

The telial stage produces conspicuous galls on the branches of *Juniperus*.

**38. *Gymnosporangium nootkatensis* (Trel.) Arth.**

Am. Jour. Bot. 3:44, 1916.  
*Uredo nootkatensis* Trelease, Alaska Harr. Exped. 5:36, 1904.  
*Aecidium sorbi* Arth. Bull. Torrey Club 33:521, 1906.  
*Gymnosporangium sorbi* (Arth.) Kern, Bull. N. Y. Bot. Gard. 7:438, 1911; N. Am. Flora 7:190, 1912.  
*Uredo chamaecyparidis-nutkaensis* Tubeuf, Nat. Zeits. Forst. Landw. 2:91, 1914.

On ROSACEAE: 0, I. Heteroecious.

*Amelanchier florida* Lindl. Glacier, July 7, 1920, C. R. Stillinger 752, Wash. Ured. 1082.

*Pyrus diversifolia* Bong. Silverton, July 5, 1920, C. R. Stillinger 740, Wash. Ured. 843.

*Pyrus occidentalis* S. Wats. Mt. Rainier, Sept. 11, 1893, J. A. Allen, Arth. Herb.; Olympic Mts., Clallam Co., June, 1900, A. D. Elmer, Arth. Herb.; Goat Mt., near Mt. Rainier, Aug. 24, 1901, E. W. D. Holway, Arth. Herb.; Olympic Mts., Queets River Valley, Jefferson Co., Aug. 15, 1907, T. C. Frye, Arth. Herb., Wash. Ured. 87; Glacier, Aug. 31, 1920, F. G. Renner, Wash. Ured. 362; Index, Aug. 1921, F. G. Renner, Wash. Ured. 200.

*Pyrus sitchensis* (Roem.) Piper. Skamania Co., Aug. 10, 1886, W. N. Suksdorf, Wash. Ured. 795; Mt. Adams, Sept. 21, 1911, W. N. Suksdorf 1095, Wash. Ured. 1226; Silverton, July 7, 1920, G. B. Posey and C. R. Stillinger 718, Wash. Ured. 824; Dosewallips River, Aug., 1920, G. Howard, Wash. Ured. 179; Skykomish, Aug. 11, 1923, A. J. Seltzer, Wash. Ured. 1187.

On PINACEAE: II, III.

*Chamaecyparis nootkatensis* (Lamb.) Spach. Mt. Rainier, Aug., 1913, C. von Tubeuf, Arth. Herb.; Silverton, July 8, 1920, G. B. Posey and C. R. Stillinger 738, Wash. Ured. 840.

This is the only *Gymnosporangium* that develops urediniospores.

**39. Gymnosporangium tubulatum Kern**

Bull. N. Y. Bot. Gard. 7:451, 1911; N. Am. Flora 7:195, 1912.  
*Roestelian tubulata* Kern, Bull. Univ. Mont. 61:64, 1910.

On ROSACEAE: 0, I. Heteroecious.

*Crataegus douglasii* Lindl. Spokane, Sept. 10, 1907, W. E. Flowers 6322, Wash. Ured. 2588.

On PINACEAE: III.

*Juniperus scopulorum* Sarg. Spokane, July 12, 1907, W. E. Flowers 6323, Wash. Ured. 2589.

**Nyssopsora Arthur****40. Nyssopsora echinata (Liv.) Arth.**

Result. Sci. Congr. Bot. Vienne 342, 1906; N. Am. Flora 7:179, 1912.  
*Triphragmium echinatum* Liv. Ann. Sci. Nat. III. 9:247, 1848.

On UMBELLIFERAE: 0, III.

*Ligusticum purpureum* C. & R. Mt. Adams, July 14, 1900, W. N. Suksdorf 599, Ellis N. Am. Ured. 1512, Arth. Herb., Wash. Ured. 712; Paradise Valley, Mt. Rainier, May, 1911, E. W. D. Holway, Arth. Herb.

*Oenanthe sarmentosa* Presl. Port Orchard, July, 1895, C. V. Piper 425, Wash. Ured. 1201; Ilwaco, September, 1922, E. Bethel; Winslow, June 9, 1923, Wash. Ured. 1810.

**Phragmidium Link****41. Phragmidium biloculare Diet. & Holw.**

Bot. Gaz. 19:305, 1894.  
*Gymnoconia bilocularis* Arth. Result. Sci. Congr. Bot. Vienne 342, 1906.  
*Earlea bilocularis* (Diet. & Holw.) Arth. N. Am. Flora 7:177, 1912.

On ROSACEAE: 0, I, III. Autoecious.

*Potentilla flabellifolia* Hook. Chiquash Mts., Aug. 18, 1892, W. N. Suksdorf 351, Arth. Herb., Wash. Ured. 615; Mt. Adams, Sept. 17, 1894, W. N. Suksdorf, 392, Arth. Herb., Wash. Ured. 643; Paradise Valley, Mt. Rainier, Aug. 24, 1901, E. W. D. Holway, N. Am. Ured. 1410, Arth. Herb.

*Potentilla nuttallii* Lehm. Wawawai, April 23, 1913, J. G. Hall, Arth. Herb.

**42. Phragmidium disciflorum (Tode) J. F. James**

Contr. U. S. Nat. Herb. 3:276, 1895; N. Am. Flora 7:171, 1912.  
*Ascophora disciflora* Tode, Fungi Meckl. 1:16, 1790.  
*Phragmidium mucronatum* Schlecht. Fl. Berol. 2:156, 1824.

*Phragmidium oblongum* Bon. Coniom. 60, 1860.

Sacc. Syll. 7:746, 1888.

*Phragmidium subcorticum* (Schr.) Wint. in Rab. Krypt. Fl. 1:228, 1881;

On ROSACEAE: 0, I, II, III. Autoecious.

*Rosa* sps. (Cultivated). Seattle, Aug. 26, 1914, Wash. Ured. 101; Tacoma, Aug. 26, 1920, Wash. Ured. 1314; Olympia, Aug. 4, 1922, Wash. Ured. 1315.

This species occurs in the United States only on cultivated roses, especially those having large and firm leaves. It is a native of Europe and probably was introduced into this country on cuttings.

### 43. *Phragmidium imitans* Arth.

N. Am. Flora 7:165, 1912.

*Phragmidium incrassatum gracile* Farl., Ellis. N. Am. Fungi 282, hyponym, 2879.

*Phragmidium gracile* Arth. Bull. Iowa Agr. Coll. Dept. Bot. 1884; 161, 1884. Not *P. gracile* Cooke, 1871,

On ROSACEAE: 0, I, II, III. Autoecious.

*Rubus leucodermis* Dougl. White Salmon River, Oct. 5, 1894, W. N. Suksdorf 415, Wash. Ured. 664; Paradise Valley, Mt. Rainier, Aug. 27, 1901, E. W. D. Holway, Arth. Herb.; Duckabush River, Aug. 9, 1912, E. Bartholomew, Barth. Fungi Columb. 4445, N. Am. Ured. 1214, Arth. Herb.

*Rubus strigosus* Michx. Cheney, June 30, 1895, S. Tucker 133, Arth. Herb.; Sumner, June, 1914, H. L. Rees, Arth. Herb.; Arlington, July 23, 1915, F. D. Heald, Arth. Herb.; Locke, Aug. 15, 1916, W. E. Flowers 6324, Wash. Ured. 2590; Coupeville, Sept. 8, 1919, Wash. Ured. 1168; Snohomish, July 27, 1920, F. G. Renner, Arth. Herb.; Stampede, Aug., 1920, F. G. Renner, Wash. Ured. 1170; Lacey, Aug. 28, 1920, Wash. Ured. 333; Bellevue, Aug. 19, 1921, A. Frank, Wash. Ured. 403; Olympia, Aug., 1921, A. Frank 225, Wash. Ured. 402; Puyallup, Aug. 19, 1921, A. Frank, Wash. Ured. 401; Ferndale, Sept. 19, 1921, G. L. Zundel, Wash. Ured. 1135; Tacoma, Oct. 8, 1921, E. Daniels, Wash. Ured. 1169; Puyallup, June 6, 1922, G. L. Zundel, Herb. W. S. C. 1018, Wash. Ured. 2812; Bay Center, Aug. 24, 1922, Wash. Ured. 1029; Ilwaco, Aug. 26, 1922, Wash. Ured. 1031; Raymond, Aug. 29, 1922, Wash. Ured. 1032; Silverdale, Sept. 27, 1922, Wash. Ured. 1061; Tracyton, Sept. 27, 1922, Wash. Ured. 1060; Poulsbo, Sept. 27, 1922, Wash. Ured. 1062; Kingston, Sept. 27, 1922, Wash. Ured. 1059; Ferncliff, Sept. 28, 1922, Wash. Ured. 1063; Port Blakeley, Sept. 29, 1922, Wash. Ured. 1065; Rolling Bay, Sept. 29, 1922, Wash. Ured. 1064; Seattle, Oct. 10, 1922, Wash. Ured. 1071.

**44. *Phragmidium ivesiae* Sydow**

Ann. Myc. 1:329. 1903; N. Am. Flora 7:174, 1912.  
*Uredo acaenae* Ellis & Ev. N. Am. Fungi 3151, hyponym, 1894.  
*Phragmidium affine* Sydow, Ann. Myc. 2:29, 1904.

On ROSACEAE: 0, I, II, III. Autoecious.

*Potentilla blaschkeana* Turez. (*P. flabelliformis* Lehm.) Pullman, Aug. 8, 1893, C. V. Piper 124, Arth. Herb., Wash. Ured. 2902; also July 20, 1915, D. C. George, Herb. W.S.C. 116, Wash. Ured. 2718; Spokane, June 29, 1884, W. N. Suksdorf 322, Barth. N. Am. Ured. 721, Arth. Herb.

*Potentilla nuttallii* Lehm. Pullman, July 2, 1898, C. V. Piper 398, Wash. Ured. 1265.

*Potentilla villosa* Pall. Silverton, July 8, 1920, C. R. Stillinger 717, Wash. Ured. 823.

**45. *Phragmidium montivagum* Arth.**

Torrey 9:24, 1909; N. Am. Flora 7:169, 1912.

On ROSACEAE: 0, I, II, III. Autoecious.

*Rosa gymnocarpa* Nutt. Spokane, June 12, 1912, W. E. Flowers 6128, Wash. Ured. 2558; Locke, Sept. 1, 1918, W. E. Flowers 6167, Wash. Ured. 2565.

*Rosa nutkana* Presl. Spokane, June 11, 1919, W. E. Flowers 7791, Wash. Ured. 2603; Locke, Aug. 15, 1916, W. E. Flowers 6400, Wash. Ured. 2601.

*Rosa rubiginosa* L. Winslow, Oct. 30, 1921, Wash. Ured. 220; Rolling Bay, Oct. 30, 1921, Wash. Ured. 219.

*Rosa* sp. Spokane, Sept., 1919, J. R. Weir 11169 and 11180, Arth. Herb.; Chelan, Sept., 1919, J. R. Weir 11167 and 11239, Arth. Herb.

**46. *Phragmidium occidentale* Arth.**

Earle, in Greene Pl. Baker 2:3, 1901; N. Am. Flora 7:166, 1912.

On ROSACEAE: 0, I, II, III. Autoecious.

*Rubus parviflorus* Nutt. White Salmon River, May 30, 1883, W. N. Suksdorf 61, Wash. Ured. 514; Blue Mts., July 4, 1892, E. R. Lake and W. R. Hull, Wash. Ured. 105; Mt. Rainier, Aug. 27, 1901, E. W. D. Holway, Arth. Herb.; Duckabush River, Aug. 9, 1912, E. Bartholomew, Barth. Fungi Columb. 4446, Arth. Herb.; Spokane, June 25, 1914, W. E. Flowers 6161, Wash. Ured. 2563; also July 21, 1919, C. R. Stillinger 397, Wash. Ured. 803; Chiwaukum, July 26, 1915, D. C. George, Herb. W. S. C. 167, Wash. Ured. 2729; Locke,

Aug. 15, 1916, W. E. Flowers 6107, Wash. Ured. 2548; Olympic Mts., July 14, 1919, G. Howard, Wash. Ured. 331; Hoquiam, July 2, 1920, C. R. Stillinger 756, Wash. Ured. 1086; Silverton, July 5, 1920, C. R. Stillinger 727, Wash. Ured. 832; Mt. Vernon, May, 1922, L. Sundquist, Wash. Ured. 968; Langley, June 15, 1922, A. Reuter, Wash. Ured. 980; Clallam Bay, Sept. 23, 1922, Wash. Ured. 1067; Forks, Sept. 24, 1922, Wash. Ured. 1066; Port Townsend, Sept. 26, 1922, Wash. Ured. 1171; Snoqualmie Falls, Nov. 10, 1923, Wash. Ured. 1273.

**47. *Phragmidium potentillae* (Pers.) P. Karst.**

Bidr. Finl. Nat. Folk 31:49, 1879; N. Am. Flora 7:174, 1912.  
*Puccinia potentillae* Pers. Syn. Fung. 229, 1801.  
*Phragmidium obtusum* Schmidt & Kunze, Deuts. Schwämme 5:5, 1816.  
*Caecoma potentillae* Schlecht. Fl. Berol. 2:121, 1824.

On ROSACEAE: 0, I, II, III. Autoecious.

*Potentilla biennis* Greene. Pullman, July 11, 1920, G. L. Zundel, Arth. Herb., Wash. Ured. 287.

*Potentilla gracilis* Dougl. Spangle, June 29, 1884, W. N. Suksdorf 145, Arth. Herb., Wash. Ured. 526; Falcon Valley, Sept. 2, 1894, W. N. Suksdorf 410, Arth. Herb., Wash. Ured. 660; Pullman, July 18, 1899, R. M. Horner 1221, Herb. W. S. C.

**48. *Phragmidium rosae-californicae* Dietel**

Hedwigia 44:125, 1905; N. Am. Flora 7:170, 1912.

On ROSACEAE: 0, I, II, III. Autoecious.

*Rosa gymnocarpa* Nutt. Nisqually River, Pierce Co., July 7, 1894, O. D. Allen 72, Arth. Herb.; Mt. Rainier, Aug. 24, 1901, E. W. D. Holway, N. Am. Ured. 1423, Arth. Herb.; Friday Harbor, June 13, 1903, T. C. Frye, Arth. Herb., Wash. Ured. 106; Pullman, July 18, 1915, F. D. Heald, Arth. Herb.; Harrington, June 6, 1919, C. R. Stillinger, Arth. Herb.

*Rosa nutkana* Presl. Seattle, Oct., 1891, C. V. Piper 23, Arth. Herb., Wash. Ured. 1313; Poulsbo, Aug. 9, 1909, E. Bartholomew, Barth. Fungi Columb. 3157, Arth. Herb.; Port Orchard, Aug. 1, 1912, E. Bartholomew, Barth. N. Am. Ured. 1019, Arth. Herb.; Cook, June 21, 1915, J. M. Jessup, Arth. Herb.; Silverton, July 8, 1920, C. R. Stillinger 726, Wash. Ured. 831; Tulalip, Aug. 21, 1920, Wash. Ured. 176; Langely, Sept., 1921, J. M. Grant, Wash. Ured. 297; Winslow, Oct. 9, 1921, Wash. Ured. 332; Mt. Vernon, May, 1922, L. Sundquist, Wash. Ured. 966.

*Rosa pisocarpa* Gray. Bainbridge Island, July 27, 1909, E. Barth-

olomew, Barth. Fungi Columb. 3158, Arth. Herb.; Wenatchee, July 15, 1912, E. Bartholomew, N. Am. Ured. 811, Arth. Herb.; Houghton, Nov. 12, 1921, Wash. Ured. 260; Medina, Nov. 12, 1921, Wash. Ured. 241; Kirkland, Nov. 12, 1921, Wash. Ured. 243; Winslow, June 28, 1922, Wash. Ured. 985.

*Rosa* sp. Bingen, July 5, 1886, W. N. Suksdorf 261, Wash. Ured. 583; Pullman, July 18, 1915, F. D. Heald and C. Sax, Herb. W. S. C. 150, Wash. Ured. 1180; Nespelem, B. F. Dana, Sept. 20, 1915, Herb. W. S. C. 372, Wash. Ured. 1181; Sumner, June 7, 1916, A. Frank 185, Wash. Ured. 438; Puyallup, Oct. 1, 1916, A. Frank 309, Wash. Ured. 435; Coupeville, June 16, 1919, A. Frank 61, Wash. Ured. 437.

#### 49. *Phragmidium speciosum* Cooke

Grevillea 3:171, 1875.

*Aregma speciosa* Fr. Syst. Myc. 3:496, 1832.

*Earlea speciosa* (Fr.) Arth. Result. Sci. Congr. Bot. Vienne 341, 1906; N. Am. Flora 7:175, 1912.

On ROSACEAE: 0, I, III. Autoecious.

*Rosa pisocarpa* Gray. Columbia River, Klickitat Co., Aug. 21, 1885, W. N. Suksdorf 233, Arth. Herb., Wash. Ured. 561; Pullman, Oct. 25, 1894, C. V. Piper 479, Arth. Herb., Wash. Ured. 2911.

*Rosa* sp. Pullman, Mar. 28, 1922, B. F. Dana, Herb. W. S. C. 980, Wash. Ured. 2806.

#### *Pileolaria* Cast.

##### 50. *Pileolaria toxicodendri* (Berk. & Rav.) Arth.

N. Am. Flora 7:147, 1907.

*Uromyces toxicodendri* Berk. & Rav., Grevillea 3:56, 1874.

*Pileolaria brevipes* Berk. & Rav., Grevillea 3:58, 1874.

*Uromyces punctata-striatum* Cooke & Hark., Grevillea 14:8, 1885.

*Uromyces brevipes* Holway, Bot. Gaz. 24:24, 1897.

On ANACARDIACEAE: 0, II, III. Autoecious.

*Rhus toxicodendron* L. Yakima, July 23, 1915, Arth. Herb., Wash. Ured. 97.

#### *Puccinia* Pers.

##### 51. *Puccinia aberrans* Peck

Bot. Gaz. 4:217, 1879.

*Micropuccinia aberrans* (Peck) Arth. & Jackson, N. Am. Flora 7:533, 1922.

On CRUCIFERAE: 0, III.

*Smelowskia calycina* Mey. Glacier Peak, Aug. 15, 1921, H. St. John, Herb. W. S. C. 950, Wash. Ured. 2805.

**52. *Puccinia absinthii* (Hedw. f.) DC.**

Fl. Fr. 6:56, 1815.

*Uredo (Puccinia) absinthii* Hedw. f., in Lam. Encycl. Meth. Bot. 8:245, 1808.  
8:245, 1808.

*Puccinia artemisiae* Fuckel, Jahrb. Nass. Ver. Nat. 23-24:55, 1870.

*Puccinia similis* E. & E. Bull. Torrey Club 25:508, 1898.

*Bullaria absinthii* (Hedw. f.) Arth. & Mains, N. Am. Flora 7:508, 1922.

On COMPOSITAE: 0, II, III.

*Artemisia dracunculoides* Pursh. Bingen, Sept. 16, 1893, W. N. Suksdorf 252, Arth. Herb., Wash. Ured. 576; Waitsburg, May 26, 1900, R. M. Horner 1464, Herb. W.S.C.; Wawawai, Nov. 28, 1902, C. V. Piper, Arth. Herb.

*Artemisia ludoviciana* Nutt. Spokane, C. V. Piper 753, Arth. Herb.; Hillyard, Sept. 20, 1914, W. E. Flowers 6038, Wash. Ured. 2535.

*Artemisia rigida* (Nutt.) Gray. Spangle, Aug., 1899, W. N. Suksdorf 348; Wawawai, Oct. 3, 1902, C. V. Piper, Arth. Herb.

*Artemisia tridentata* Nutt. Bingen, June 28, 1902, W. N. Suksdorf 791, Wash. Ured. 729; Wenatchee, July 15, 1912, E. Bartholomew, Barth. Fungi Columb. 4450, Barth. N. Am. Ured. 1216, Arth. Herb.; Yakima, Aug., 1915, Wash. Ured. 77.

There are only two species of rust found in Washington having telia on *Artemisia*, the above species, which is a brachy-form, and *P. millefolii* (Cf. 131), a micro-form. The teliospores of these two species are quite similar and might easily be confused if only telia were present. *Artemisia* is also the aecial host of *P. universalis*.

**53. *Puccinia abundans* (Pk.) Jackson**

Brooklyn Bot. Gard. Mem. 1:229, 1918.

*Aecidium abundans* Pk. Bot. Gaz. 3:34, 1878.

*Puccinia crandallii* Pam. & Hume, Proc. Davenport Acad. Sci., 7:250, 1899.

*Puccinia kreageri* Ricker, Jour. Myc. 11:114, 1905.

*Dicaeoma abundans* (Pk.) Arth. & From., N. Am. Flora 7:328, 1920.

On CAPRIFOLIACEAE: 0, I. Heteroecious.

*Symphoricarpos racemosus* Michx. Falcon Valley, May 29, 1882, W. N. Suksdorf 14, Wash. Ured. 501; Pullman, June 2, 1894, C. V. Piper 182, Herb. W. S. C., Wash. Ured. 1287; also May 24, 1921, C. S. Parker, Herb. W.S.C. 768, Wash. Ured. 2777; Kalama, June 18, 1911, T. C. Frye, Wash. Ured. 339; Spokane River, June 10, 1914, W. E. Flowers 6289, Wash. Ured. 2580; Spokane, Aug. 15, 1914, W. E. Flowers 601, Wash. Ured. 2510; Friday Harbor, June 29, 1919, G. Howard, Wash. Ured. 133; Black Diamond, July 2, 1922, A. J. Seltzer, Wash. Ured. 990.



*Symphoricarpos* sp. Bingen, June 28, 1900, W. N. Suksdorf 590, Wash. Ured. 705; Flat Top Island, July 6, 1919, G. Howard, Wash. Ured. 1188.

On POACEAE: II, III.

*Festuca subulata* Trin. Clark Spring, June 26, 1902, F. O. Kreager, Arth. Herb.

#### 54. *Puccinia albulensis* P. Magn.

Ber. Deuts. Bot. Ges. 7:169, 1890.

*Puccinia veronicae* Schum., Hedwigia 19:164, 1880. Not *P. veronicae* Schroet., 1879.

*Micropuccinia albulensis* (P. Magn.) Arth. & Jackson, Bull. Torrey Club 48:42, 1921; N. Am. Flora 7:566, 1922.

On SCROPHULARIACEAE: 0, III.

*Veronica cusickii* Gray. Mt. Rainier, Aug. 22, 1901, E. W. D. Holway, Arth. Herb.

*Vernonia scutellata* L. Mt. Adams, W. N. Suksdorf 367, Wash. Ured. 623.

#### 55. *Puccinia allii* (DC.) Rudolphi

Linnaea 1:392, 1829.

*Xyloma allii* DC. Fl. Fr. 6:156, 1815.

*Puccinia alliorum* Corda, Ic. Fung. 4:12, 1840.

*Puccinia rotundata* Bon. Abh. Nat. Ges. Halle 5:219, 1860.

*Puccinia blasdalei* Dietel & Holway; Dietel, Erythea 1:248, 1893.

*Dicaeoma allii* (DC.) Kuntze, Rev. Gen. 3<sup>d</sup>:467, 1898; N. Am. Flora 7:373, 1920.

On LILIACEAE: 0, I, II, III. Autoecious.

*Allium acuminatum* Hook. Pullman, June 22, 1893, C. V. Piper, Phanerogamic specimen 1885, Torrey Herb. N. Y. Bot. Garden, Arth. Herb.; also F. L. Pickett, Herb. W. S. C. 356, Wash. Ured. 2755; Bingen, June 2, 1894, W. N. Suksdorf 382, N. Am. Ured. 18, Arth. Herb., Wash. Ured. 631; Rockland, Apr. 18, 1901, W. N. Suksdorf 647, Arth. Herb., Wash. Ured. 721; Spokane, Aug. 12, 1914, W. E. Flowers 6140, Wash. Ured. 1152; Colfax, May 1, 1922, C. S. Parker, Herb. W. S. C. 911, Wash. Ured 2807.

"This rust may be distinguished from other *Allium* rusts by the strongly developed stroma in the telial sori, and the tendency to form confluent telia covering large areas on the stems and leaves. The teliospores are large (16-26 by 40-61  $\mu$ ), thickened to 4-10  $\mu$  at the apex." Jackson.

#### 56. *Puccinia ambigua* (Alb. & Schw.) Lagerh.

Bubäk Sitz. -ber. Böhm. Ges. Wiss. 1898<sup>m</sup>:14, 1898.

*Aecidium galii ambiguum* Alb. & Schw. Consp. Fung. 116, 1805.

*Puccinia difformis* Kunze, Myc. Hefte 1:71, 1817.

*Allodus ambigua* (Alb. & Schw.) Arth. Result. Sci. Congr. Bot. Vienne 345, 1906; N. Am. Flora 7:473, 1921.

On RUBIACEAE: 0, I, III. Autoecious.

*Galium aparine* L. Bingen, May 21, 1900, W. N. Suksdorf 591, Arth. Herb., Wash. Ured. 706; Pullman, July 18, 1915, F. D. Heald & C. Sax, Herb. W.S.C. 151, Wash. Ured. 2726.

As indicated above this species has no uredinia, which fact distinguishes it from *P. punctata* (cf. 150) which occurs on the same host in Washington.

### 57. *Puccinia bullata* (Pers.) Schroet.

Beitr. Biol. Pfl. 3:74, 1879. Not *P. bullata* Link 1815, nor *P. bullata* Schw., 1822.

*Uredo bullata* Pers. Ann. Bot. Usteri 15:37, 1795.

*Uredo angelicae* Schum. Enum. Pl. Saell. 2:233, 1803.

*Puccinia archangelicae* A. Blytt, For. Vid.-Selsk. Christ. 6:51, 1896.

*Puccinia angelicae* Fuckel, Jahrb. Nass. Ver. Nat. 23-24:52, 1870.

*Bullaria bullata* (Pers.) Arth. Result. Sci. Congr. Bot. Vienne 346, 1906; N. Am. Flora 7:490, 1922.

On UMBELLIFERAE: 0, II, III.

*Angelica genuflexa* Nutt. Falcon Valley, Aug. 2, 1883, W. N. Suksdorf 24, Wash. Ured. 1323; Eatonville, Aug. 28, 1901, E. W. D. Holway, Arth. Herb.

*Angelica* sp. Silverton, July 8, 1920, C. R. Stillinger 725, Wash. Ured. 830.

This species is rare in Washington. It is distinguished from *P. ellisii*, another brachy-form found on the same host, by the fact that the teliospores are smooth while in the latter they are closely and finely verrucose.

### 58. *Puccinia anomala* Rostr.

Thüm. Flora 61:92, 1878.

*Puccinia straminis simplex* Körn. Land. Forstw. Zeit. No. 50, 1865.

*Puccinia hordei* Otth., Mitt. Nat. Ges. Bern 1870:114, 1871. Not *P. hordei* Fuckel, 1860.

*Puccinia simplex* Erikss. & Henn. Zeits. Pflanzenkr. 4:260, 1894. Not *P. simplex* Peck, 1881.

*Dicaeoma anamalum* (Rostr.) Arth. & From., N. Am. Flora 7:339, 1920.

On POACEAE: II, III. Heteroecious. (0, I probably on the Liliaceae).

*Hordeum vulgare* L. Puyallup, July 18, 1918, A. Frank, Wash. Ured. 446; Coupeville, July 18, 1919, G. L. Zundel, Wash. Ured. 138; Winslow, July 25, 1920, Wash. Ured. 168.

This is the leaf rust of barley. In 1914 Tranzschel, working in Russia, succeeded in obtaining the aecial stage of this rust on *Ornithogalum umbellatum*, the Star-of-Bethlehem. In 1922 Mains and Jackson, using telial material collected in the state of Washington, confirmed this result (Phytopath. 18: 49-60, 1923, and Jour. Agri. Res.

28:1124-1125, 1924). The rust is probably more common in the state than the above collections would indicate.

#### 59. *Puccinia antirrhini* Diet. & Holw.

Hedwigia 36:298, 1897; N. Am. Flora 7:594, 1922.  
*Puccinia adenostegiae* Arth. Bull. Torrey Club 29:231, 1902.  
*Dicaeoma antirrhini* H. S. Jackson, Proc. Ind. Acad. Sci., 1915:443, 1916.  
*Puccinia cordylanthi* Blasdale, Univ. Calif. Publ. Bot. 7:134, 1918.

On SCROPHULARIACEAE: II, III. Heteroecious. (0, I uncertain).

*Antirrhinum majus* L. Walla Walla, June 23, 1921, B. F. Dana, Herb. W.S.C. 803, Wash. Ured. 2785; Langley, Aug., 1921, J. M. Grant, Wash. Ured. 298; Lacey, July 15, 1922, R. Lungreen, Wash. Ured. 1173; Yelm, July 15, 1922, R. Lungreen, Wash. Ured. 1172; Vancouver, Aug. 4, 1922, Wash. Ured. 1108; Bothell, Aug. 10, 1922, Wash. Ured. 1822; Seattle, Nov. 18, 1922, Wash. Ured. 1118; also Sept. 5, 1923, Wash. Ured. 1821; Pomeroy, Sept. 15, 1824, M. A. Thompson, Wash. Ured. 1341.

This is the snap-dragon rust. It probably originated in California from some native species. The fact that the mycelium from the basiospore does not infect snap-dragons indicates that it is a heteroecious rust. It is quite generally distributed throughout the state of Washington, both in gardens and greenhouses where snap-dragons are grown.

#### 60. *Puccinia apocrypta* Ellis & Tracy

Jour. Myc. 6:76, 1890.  
*Aecidium hydrophylli* Peck, Bull. Buffalo Soc. Nat. Sci. 1:68, 1873 (Not *Dicaeoma hydrophylli* Kuntze, 1898).  
*Dicaeoma apocryptum* (Ellis & Tracy) Kuntze, Rev. Gen. 3:467, 1898; N. Am. Flora 7:332, 1920.

On HYDROPHYLLACEAE: 0, I Heteroecious. (II, III on Poaceae).

*Hydrophyllum albifrons* Heller. Wawawai, June 9, 1894, C. V. Piper, Herb. W.S.C.; Pullman, May 20, 1916, B. F. Dana, Herb. W. S.C. 268, Wash. Ured. 2744.

*Hydrophyllum capitatum* Dougl. Falcon Valley, June 1, 1883, W. N. Suksdorf 379, Wash. Ured. 515; Bingen, May 11, 1894, W. N. Suksdorf 379, Wash. Ured. 628; Pullman, May 25, 1894, C. V. Piper, Wash. Ured. 2894; Wawawai, June 9, 1894, C. V. Piper, Herb. W.S.C.; also Apr. 27, 1913, J. G. Hall, Arth. Herb.; Waitsburg, Apr. 4, 1900, R. M. Horner 1421, Herb. W.S.C.; Snake River, Whitman Co., Apr. 21, 1916, B. F. Dana, Herb. W.S.C. 247, Wash. Ured. 2740; Pullman, May 3, 1916, B. F. Dana, Herb. W.S.C. 251, Wash. Ured. 2741; Locke, June 7, 1916, W. E. Flowers 6158, Wash. Ured. 2561;

Colfax, May 1, 1922, C. S. Parker, Herb. W.S.C. 994, Wash. Ured. 2809.

*Hydrophyllum tenuipes* Heller. Bingen, May 29, 1886, W. N. Suksdorf 340, Wash. Ured. 613; Lower Cascades, Skamania Co., May 29, 1886, W. N. Suksdorf; Renton, Apr. 17, 1910, T. C. Frye, Wash. Ured. 70; Fort Lawton, May 24, 1921, Wash. Ured. 198; Auburn, May 25, 1924, M. C. McConihe, Wash. Ured. 1334.

*Hydrophyllum* sp. Pullman, July 2, 1915, F. D. Heald & D. C. George, Herb. W.S.C. 71, Wash. Ured. 2712.

*Nemophila parviflora* Dougl. White Salmon River, Klickitat Co., May 2, 1896, W. N. Suksdorf 378, Wash. Ured. 627.

*Phacelia circinata* Jacq. Little White Salmon, June 26, 1895, W. N. Suksdorf 458, Wash. Ured. 671; Bingen, Mar. 29, 1902, W. N. Suksdorf 1053, Wash. Ured. 753.

ON POACEAE: II, III.

*Elymus glaucus* Buckl. Bingen, June 28, 1900, W. N. Suksdorf 602, Arth. Herb., Wash. Ured. 715.

**61. *Puccinia areolata* Diet. & Holw.**

Bot. Gaz. 19:304, 1894.

*Dicaeoma areolatum* (Diet. & Holw.) Kuntze, Rev. Gen. 3:467, 1898; N. Am. Flora 7:390, 1920.

ON RANUNCULACEAE: 0, I, II, III. Autoecious.

*Caltha biflora* DC. Chiquash Mt. (type locality), Aug. 12, 1886, W. N. Suksdorf 318, N. Am. Ured. 1523, Arth. Herb., Wash. Ured. 594; Olympic Mts., Aug., 1895, C. V. Piper 461, Wash. Ured. 2916; Bingen, July 10, 1899, W. N. Suksdorf 1100, Wash. Ured. 1320; Granite, July 11, 1920, W. E. Morgan, Arth. Herb.

**62. *Puccinia arnicalis* Peck**

Bot. Gaz. 6:227, 1881; N. Am. Flora 7:603, 1922.

ON COMPOSITAE: II, III. (0, I unknown).

*Arnica fulgens* Pursh. Kamiak Butte, May 24, 1921, C. S. Parker, Herb. W.S.C. 924.

This rust has been reported only from the Rocky Mountain and Pacific Coast regions. The teliospores are not thickened at the apex and are finely verrucose. The aecia of *Uromyces junci* may occur on the same host.

**63. *Puccinia asarina* Kunze**

Myk. Hefte 1:70, 1817.

*Puccinia asari* Link, in Willd. Sp. Pl. 6:68, 1825.

*Micropuccinia asarina* (Kunze) Arth. & Jackson, Bull. Torrey Club 48:40, 1921; N. Am. Flora 7:525, 1922.

## On ARISTOLOCHIACEAE: 0, III.

*Asarum caudatum* Lindl. Little White Salmon, W. N. Suksdorf 386, N. Am. Ured. 525, Wash. Ured. 636; Chenowith, Aug. 12, 1896, W. N. Suksdorf 368b, Wash. Ured. 635; Locke, Aug. 1, 1915, W. E. Flowers 6137, Wash. Ured. 1227; Seattle, July 15, 1919, Wash. Ured. 992.

**64. *Puccinia asparagi* DC.**

Fl. Fr. 2:595, 1805.

*Dicaeoma asparagi* (DC) Kuntze, Rev. Gen. 3:467, 1898; N. Am. Flora 7:376, 1920.

## On LILIACEAE: 0, I, II, III. Autoecious.

*Asparagus officinalis* L. Clarkston, June 6, 1915, B. F. Dana, Herb. W.S.C. 88, Wash. Ured. 2716; Pullman, July 21, 1920, G. L. Zundel, Wash. Ured. 167.

This is the asparagus rust which often produces serious damage.

**65. *Puccinia asperifolii* (Pers.) Wettst.**

Verh. Zool.-Bot. Ges. Wien 35:541, 1886.

*Aecidium asperifolii* Pers. Obs. Myc. 1:97, 1796.

*Puccinia rubigo-vera* Wint. in Rab. Krypt. Fl. 1:217, 1881.

*Puccinia dispersa* Eriks. Zeits. Pflanzenkr. 4:257, 1894.

*Dicaeoma asperifolii* (Pers.) Kunze, Rev. Gen. 3:466, 1898; N. Am. Flora 7:331, 1920.

*Puccinia secalina* Grove, Brit. Rust. Fungi 261, 1913.

## On POACEAE: II, III. (0, I probably on Boraginaceae).

*Secale cereale* L. Bingen, June 24, 1896, W. N. Suksdorf 553, Wash. Ured. 681; Bremerton, July 25, 1912, E. Bartholomew, Barth. N. Am. Ured. 1220, Arth. Herb.; Pullman, Aug. 30, 1916, F. D. Heald & D. C. George, Herb. W.S.C. 416, Wash. Ured 1298.

This is the leaf rust of rye and is evidently more widely distributed throughout the state than the above collections would indicate. It has usually gone under the name of *P. rubigo-vera* (DC.) Wint., which is applied to most sub-epidermal grass rusts not having strongly marked morphological characters.

The teliospores of this rust, collected from the state of Washington, have been shown by Mains and Jackson to form aecia on *Anchusa officinalis* (Phytopath. 13:49-50, 1923, and Jour. Agri. Res. 28:1119-1124, 1924).

**66. *Puccinia asperior* Ellis & Ev.**

Bull. Washburn Lab. Nat. Hist. 1:3, 1884.

*Puccinia oregonensis* Earle, Bull. N. Y. Bot. Gard. 2:349, 1902.

*Allodus oregonensis* Arth. Result. Sci. Congr. Bot. Vienne 345, 1906.

*Allodus asperior* (Ellis & Ev.) Orton, Mem. N. Y. Bot. Gard. 6:193, 1916; N. Am. Flora 7:462, 1921.

On UMBELLIFERAE: 0, I, III. Autoecious.

*Leptotaenia dissecta* Nutt. Bingen (type locality), June, 1883, W. N. Suksdorf 86, Barth. N. Am. Ured. 1219, Wash. Ured. 522.

### 67. *Puccinia asteris* Duby

Bot. Gall. 2:888, 1830.

*Puccinia magnoecia* Ellis & Ev. Bull. Torrey Club 22:59, 1895.

*Micropuccinia asteris* (Duby) Arth. & Jackson, Bull. Torrey Club 48:40, 1921; N. Am. Flora 7:575, 1922.

On COMPOSITAE: 0, III.

*Aster conspicuus* Lindl. Hillyard, Sept. 20, 1914, W. E. Flowers 6006, Wash. Ured. 2505.

*Aster foliaceus frondeus* Gray. Lake Chelan, Aug., 1892, E. R. Lake and W. R. Hull 187, Arth. Herb.

*Aster fremontii* (T. & G.) Gray. Pullman, June 29, 1898, C. V. Piper 385, Arth. Herb.

*Aster laevis geyeri* Gray. Spokane, Oct. 1, 1893, A. M. Johnson 1169, Arth. Herb.; Hillyard, July 20, 1914, W. E. Flowers 6007, Wash. Ured. 2506.

*Aster* sp. Chelan, Aug., 1916, J. R. Weir 11222, Arth. Herb.

### 68. *Puccinia asterum* (Schw.) Kern

Mycologia 9:224, 1917.

*Aecidium asterum* Schw. Schrift. Nat. Ges. Leipzig 1:67, 1822.

*Aecidium solidaginis* Schw. Schrift. Nat. Ges. Leipzig 1:68, 1822.

*Puccinia extensicola* Plowr. Brit. Ured. Ustil. 181, 1889.

*Puccinia caricis-erigerontis* Arth. Jour. Myc. 8:53, 1902.

*Puccinia caricis-asteris* Arth. Jour. Myc. 8:54, 1902.

*Puccinia caricis-solidaginis* Arth. Bot. Gaz. 35:21, 1903.

*Dicaeoma astrum* (Schw.) Arth. & Kern, N. Am. Flora 7:362, 1920.

On COMPOSITAE: 0, I. Heteroecious.

*Aster occidentalis intermedius* Gray. Falcon Valley, May 19, 1884, W. N. Suksdorf 164, Wash. Ured. 534.

*Aster punicens* L. Spokane, July 14, 1914, W. E. Flowers 6005, Wash. Ured. 2504.

*Aster* sp. Lake Chelan, Sept., 1916, J. R. Weir 11235, Arth. Herb.

*Eucephalus ledophyllus* (Gray) Greene. Chiquash Mt., Sept. 10, 1902, W. N. Suksdorf 800, Arth. Herb., Wash. Ured. 730.

On CYPERACEAE: II, III.

*Carex bolanderi* Olney. Seattle, June, 1892, C. V. Piper 78, Arth. Herb.; Cedar River, April 8, 1894, A. M. Parker, Wash. Ured. 64; Renton, Aug. 8, 1894, C. V. Piper 299, Wash. Ured. 1230.

*Carex laeviculmis* Meensch. Bremerton, Aug., 1912, E. Bartholomew, Barth. N. Am. Ured. 827, Arth. Herb.

*Carex leptopoda* Mackenzie. Renton, Aug. 8, 1894, C. V. Piper 299, Arth. Herb.; Winslow, June 12, 1922, Wash. Ured. 1001; Seattle, Oct., 1922, A. J. Seltzer.

*Carex multimoda* Bailey. Hillyard, Sept. 20, 1914, W. E. Flowers 6331, Wash. Ured. 2595.

*Carex stipata* Muhl. Chehalis, July 3, 1922, Wash. Ured. 1003.

*Carex tenella* Schkuhr. Duckabush River, Aug. 9, 1912, E. Bartholomew, Barth. Fungi Columb. 4455, Barth. N. Am. Ured. 1226, Arth. Herb.

"This species is separable from all other American species of *Puccinia* on *Carex* by the presence of two pores in the upper part of the rather small (12-19 by 16-23  $\mu$ ) urediniospores and the medium-sized (12-20 by 35-50  $\mu$ ) teliospores.

"The aecia of this species should not be confused with those of *P. stipae* which occur on the same generic hosts and other Compositae in the West. In *P. asterum* the aecia are cupulate, the peridium conspicuous, the spores globoid, nearly colorless and small (11-15 by 13-18  $\mu$ ). In *P. stipae* the aecia occur on hypertrophied areas, the individual cups are gall-like and open by a central aperture, the peridium is evanescent, the spores are cinnamon brown, globoid, large (21-26 by 22-29  $\mu$ )." Jackson.

#### 69. *Puccinia atrofusca* (Dud. & Thomp.) Holway

Jour. Myc. 10:228, 1904.

*Dicaeoma atrofuscum* (Dud. & Thomp.) Arth. Result. Sci. Congr. Bot. Vienne 343, 1906; N. Am. Flora 7:353, 1920.

On CYPERACEAE: II, III. (0, I unknown).

*Carex douglasii* Boott. Pullman, July 22, 1899, R. M. Horner 1298, Herb. W.S.C.; Hanford, June 2, 1919, C. R. Stillinger, Arth. Herb.; Spokane, May 18, 1922, W. E. Flowers 6348, Wash. Ured. 1247.

"This species possesses amphispores which were first mistaken for the teliospores of a *Uromyces*. It may be distinguished from other *Carex* rusts by the presence of the amphispores together with the normal urediniospores, the latter are 20-26  $\mu$  long and thin walled, 1.5-2  $\mu$  thick. The aecial connection is unknown. It is known only from the Rocky mountains and Pacific coast regions." Jackson.

#### 70. *Puccinia balsamorhizae* Peck

Bull. Torrey Club 11:49, 1884.

*Trichobasis balsamorhizae* Pk. Bot. Gaz. 6:276, 1881.

*Bullaria balsamorhizae* (Peck) Arth. & Mains, N. Am. Flora 7:506, 1922.

On COMPOSITAE: 0, II, III. Autoecious.

*Balsamorhiza deltoidea* Nutt. Falcon Valley, Aug. 3, 1884, W. N. Suksdorf 178, Arth. Herb., Wash. Ured. 545.

*Balsamorhiza sagittata* (Pursh) Nutt. Pullman, Oct., 1893, C. V. Piper, Ellis & Ev. Fungi Columb. 1380, Arth. Herb.; also July 10, 1919, G. L. Zundel, Wash. Ured. 137; Wenatchee, July 15, 1912, E. Bartholomew, Barth. Fungi Columb. 4454, Barth. N. Am. Ured. 927; Spokane, Aug. 10, 1913, W. E. Flowers 6089, Wash. Ured. 2544; Pullman, July 20, 1915, D. C. George, Herb. W.S.C. 117, Wash. Ured. 2719; Locke, Aug. 20, 1917, W. E. Flowers 6093, Wash. Ured. 2546.

*Balsamorhiza* sp. Pullman, July 14, 1916, B. F. Dana, Herb. W.S.C. 365.

### 71. *Puccinia bistortae* (Strauss) DC.

Fl. Fr. 6:61, 1815.

*Uredo polygoni bistortae* Strauss, Ann. Wett. Ges. 2:103, 1810.

*Dicaeoma bistortae* (DC.) Kuntze, Rev. Gen. 3:468, 1898; N. Am. Flora 7:383, 1920.

On POLYGONACEAE: II, III. Heteroecious. (0, I on Umbelliferae).

*Polygonum bistortoides* Pursh. Falcon Valley, June 26, 1886, W. N. Suksdorf 247, Wash. Ured. 572; also June 24, 1893, W. N. Suksdorf, Barth. N. Am. Ured. 224, Arth. Herb.

*Polygonum newberryi* Small. Skamania Co., Aug. 10, 1886, W. N. Suksdorf 317, Barth. N. Am. Ured. 532, Wash. Ured 593; Chelan, Aug., 1916, J. R. Weir, Arth. Herb.

This rust has been reported only from Washington and Oregon. It is distinguished from other rusts on *Polygonum* by "the medium-sized teliospores (16-21 by 26-35  $\mu$ ) with walls of uniform thickness, without hyaline umbo."

### 72. *Puccinia calochorti* Peck

Bot. Gaz. 6:228, 1881.

*Puccinia anachoreta* Ellis & Hark. Bull. Calif. Acad. 1:14, 1884.

*Puccinia holwayi* Dietel, Hedwigia 32:29, 1893.

*Allodus calochorti* (Peck) Arth. Result. Sci. Congr. Bot. Vienne 345, 1906; N. Am. Flora 7:455, 1921.

On LILIACEAE: 0, I, II. Autoecious.

*Calochortus elegans* Pursh. Skamania Co., July 19, 1894, W. N. Suksdorf 1077; Wash. Ured. 774; Chiquash Mt., July 22, 1894, W. N. Suksdorf 1079, Wash. Ured. 776; Mt. Adams, July 22, 1902, W. N. Suksdorf 320 (III), 321 (I), Wash. Ured. 596.

*Calochortus longebarbatus* Wats. Falcon Valley, June 12, 1902, W. N. Suksdorf 248, N. Am. Ured. 533, Wash. Ured. 573.



**73. *Puccinia chelonis* Diet. & Holw.**

Hedwigia 36:297, 1897.

*Micropuccinia chelonis* (Diet. & Holw.) Arth. & Jackson, N. Am. Flora 7:564, 1922.

On SCROPHULARIACEAE: 0, III.

*Chelone nemorosa* Dougl. Chiquash Mt., Aug. 27, 1895, W. N. Suksdorf 455, N. Am. Ured. 128, Wash. Ured. 668; Mt. Adams, Sept. 3, 1900, W. N. Suksdorf 596, Wash. Ured. 709; Mt. Adams, East side, Aug. 25, 1907, W. N. Suksdorf 1058, Wash. Ured. 757.

This rust is reported on the same host in Oregon.

**74. *Puccinia cicutae* Lasch**

Herb. Viv. Myc. 787, 1845.

*Dicaeoma cicutae* (Lasch) Kuntze, Rev. Gen. 3:468, 1898; N. Am. Flora 7:398, 1920.

On UMBELLIFERAE: 0, I, II, III. Autoecious.

*Cicuta occidentalis* Greene. Wapato, Sept. 13, 1921, G. L. Zundel, Wash. Ured. 1136.

**75. *Puccinia circaeae* Pers.**

Neues Mag. Bot. 1:119, 1794.

*Micropuccinia circaeae* (Pers.) Arth. & Jackson, Bull. Torrey Club 48:40, 1921; N. Am. Flora 7:548, 1922.

On ONAGRACEAE: 0, III.

*Circaea alpina* L. Locke, Aug. 25, 1915, W. E. Flowers 6141, Wash. Ured. 1151.

*Circaea pacifica* Asch. & Magn. Falcon Valley, Aug. 2, 1884, W. N. Suksdorf 177, Wash. Ured. 544; Renton, July 14, 1892, C. V. Piper 113, Arth. Herb., Wash. Ured. 2882; Cedar River, Aug. 8, 1894, A. Parker, Wash. Ured. 65; Blue Mt., Columbia Co., June 23, 1897, R. M. Horner 1205, Herb. W.S.C.; Bremerton, July 22, 1912, E. Bartholomew, Fungi Columb. 4456, Herb. W.S.C.; Newport, July, 1915, J. R. Weir 45, Arth. Herb.; Puyallup, July 31, 1918, A. Frank, Wash. Ured. 417; Friday Harbor, July, 1919, G. Howard, Wash. Ured. 290; Silverton, July 7, 1920, C. R. Stillinger 750, Wash. Ured. 1081; Kirkland, July 10, 1920, C. R. Stillinger & G. B. Posey 701, Wash. Ured. 810; Randle, Aug. 3, 1920, J. S. Boyce, Wash. Ured. 2856.

**76. *Puccinia cirsii* Lasch**

Rab. Fungi Eur. 89, 1859.

*Puccinia californica* Dietel, Bot. Gaz. 18:254, 1893.

*Puccinia laschii* Lagerh. Tromsø Mus. Aarsh. 17:63, 1895.

*Puccinia inclusa* Sydow, Monog. Ured. 1:56, 1902.

*Bullaria cirsii* (Lasch) Arth. Result. Sci. Congr. Bot. Vienne 346, 1906; N. Am. Flora 7:509, 1922.

## On COMPOSITÆ: 0, II, III. Autoecious.

*Cirsium breweri* (Gray) Jepson. Pullman, Aug. 31, 1894, C. V. Piper 506, Wash. Ured. 2909.

*Cirsium edule* Nutt. Renton, July 14, 1892, C. V. Piper, Arth. Herb.; Seattle, Aug., 1892, C. V. Piper 46, Herb. W.S.C., Wash. Ured. 1306.

*Cirsium lanceolatum* (L.) Scop. Spokane, July 4, 1914, W. E. Flowers 6030, Wash. Ured. 2528.

*Cirsium polousense* Piper. Pullman, Sept. 4, 1920, G. L. Zundel, Wash. Ured. 1274.

*Cirsium remotifolium* (Hook.) DC. Skamania Co., Apr. 25, 1886 and Oct. 2, 1894, W. N. Suksdorf 316, Wash. Ured. 592.

*Cirsium undulatus* (Nutt.) Spreng. Spokane, Aug. 28, 1898, C. V. Piper 547, Wash. Ured. 2830.

77. *Puccinia claytoniata* (Schw.) Peck

Bull. N. Y. State Mus. 6:226, 1899.

*Caeoma* (*Aecidium*) *claytoniata* Schw. Trans. Am. Phil. Soc. II, 4:294, 1832.  
*Puccinia mariae-wilsoni* G. W. Clinton, Bull. Buff. Soc. Nat. Hist. 1:66, 1873.

*Allodus claytoniata* (Schw.) Arth. Result. Sci. Congr. Bot. Vienne 345, 1906; N. Am. Flora 7:457, 1921.

## On PORTULACACEÆ: 0, I, III. Autoecious.

*Claytonia asarifolia* Bong. Mt. Adams, Aug. 19, 1886, W. N. Suksdorf 322, Barth. N. Am. Ured. 133, Wash. Ured. 597; Chiquash Mts., Aug. 10, 1886, W. N. Suksdorf 273, Arth. Herb.; Skamania Co., Aug. 10, 1886, W. N. Suksdorf 131, Holway Herb.

78. *Puccinia clematidis* (DC.) Lagerh.

Tromsö Mus. Aarsh. 17:54, 1895.

*Aecidium clematidis* DC. Fl. Fr. 2:243, 1805.

*Aecidium aquilegiae* Pers. Ic. Pict. 58, 1806.

*Puccinia elymi* Westend. Bull. Acad. Brux. 18:408, 1851.

*Puccinia tomipara* Trel. Trans. Wis. Acad. Sci. 6:127, 1885.

*Puccinia perplexans* Plowr. Quart. Jour. Micr. Sci. 25:164, 1885.

*Puccinia persistens* Plowr. Brit. Ured. 180, 1889.

*Puccinia agrostidis* Plowr. Gard. Chron. III, 8:139, 1890.

*Puccinia agropyri* Ellis & Ev. Jour. Myc. 7:131, 1892.

*Puccinia aquilegiae* Lagerh. Tromsö Mus. Aarsh. 17:47, 1895.

*Puccinia adpersa* Dietel & Holway, Erythra 3:81, 1895.

*Puccinia triticina* Eriksson, Ann. Sci. VIII, 9:270, 1899.

*Aecidium delphinii* Barth. Jour. Myc. 8:173, 1902.

*Puccinia cinerea* Arth. Bull. Torrey Club 34:583, 1907.

*Puccinia missouriensis* Arth. Bull. Torrey Club 45:146, in part, 1918.

*Dicaeoma clematidis* (DC.) Arth. Result. Sci. Congr. Bot. Vienne 344, 1906; N. Am. Flora 7:333, 1920.

## On RANUNCULACEÆ: O, I. Heterocisus.

*Actaea spicata arguta* (Nutt.) Torr. Prindle, May 26, 1824, W. N. Suksdorf 1102, Wash. Ured. 1340.

*Anemone piperi* Britton. Spokane, July, 1914, J. R. Weir 83, Arth. Herb.

*Aquilegia formosa* Fisch. Skamania Co., Aug. 12, 1886, W. N. Suksdorf 290, Arth. Herb., Wash Ured. 586; Silverton, July 8, 1920, C. R. Stillinger & G. B. Posey 716, Wash. Ured. 822.

*Clematis hirsutissima* Pursh. Pullman, June 2, 1894, C. V. Piper 321, Wash. Ured. 2896; Spokane, July 10, 1914, W. E. Flowers 6015, Wash. Ured. 2514.

*Clematis ligusticifolia* Nutt. Spangle, June 17, 1889, W. N. Suksdorf 360, Wash. Ured. 622; Whitman Co., 1892, E. R. Lake & W. R. Hull 215, Arth. Herb.; Spokane, July 11, 1910, W. E. Flowers 6012, Wash. Ured. 2511; Wenatchee, July 15, 1912, E. Bartholomew, Arth. Herb., Barth. Fungi Columb. 4457; Yakima, July 5, 1915, Wash. Ured. 126; Waitsburg, July 20, 1919, Wash. Ured. 223; Wawawai, May 15, 1921, C. S. Parker, Herb. W.S.C. 922, Wash. Ured. 2801.

*Clematis* sp. Pullman, June 15, 1915, H. M. Woolman, Herb. W.S.C. 37, Wash. Ured. 2707.

*Delphinium menziesii* DC. Spokane, May 8, 1914, W. E. Flowers 6291, Wash. Ured. 2582.

*Ranunculus glaberrimus* Hook. Pullman, May 7, 1894, C. V. Piper 257, Wash. Ured. 2892; Spokane, Mar. 24, 1914, W. E. Flowers 6238, Wash. Ured. 2578; Spangle, Apr. 24, 1916, W. N. Suksdorf 1063, Wash. Ured. 761; Colfax, May 1, 1922, C. S. Parker, Herb. W.S.C. 992, Wash. Ured. 2808.

*Ranunculus hebecarpus* H. & A. Bingen, Dec. 28, 1893, W. N. Suksdorf 258, Wash. Ured. 580.

*Ranunculus occidentalis* Nutt. Bingen, May 14, 1897, W. N. Suksdorf 457, Wash. Ured. 670.

*Thalictrum occidentale* Gray. Pullman, June 20, 1893, C. V. Piper, Rocky Mt. Herb. 5707, Arth. Herb.; Locke, July 20, 1915, W. E. Flowers 6027, Wash. Ured. 2525; Chesaw, July 7, 1921, C. S. Parker, Herb. W.S.C. 868, Wash. Ured. 2793; Sol Duc Hot Springs, July 14, 1920, J. S. Boyce 628, Wash. Ured. 2855; Twisp Pass, July 20, 1921, C. S. Parker, Herb. W.S.C. 918, Wash. Ured. 2799.

## On POACEÆ: II, III.

*Agropyron repens* (L.) Beauv. Vancouver, Sept. 25, 1912, E. Bartholomew, Barth. N. Am. Ured. 1144, Arth. Herb.; Coupeville, Aug. 26, 1918, Wash. Ured. 128; Seattle, Sept. 8, 1918, Wash. Ured.

341; Granite Falls, Sept. 16, 1921, G. L. Zundel, Wash. Ured. 1157; Kirkland, Nov. 12, 1921, Wash. Ured. 248; Bothell, Nov. 12, 1921, Wash. Ured. 249; Medina, Nov. 2, 1921, Wash. Ured. 265.

*Agropyron riparium* Scribn. & Smith. Kirkland, Nov. 12, 1921, Wash. Ured. 246.

*Agropyron spicatum* (Pursh) S. & S. Bingen, June 28, 1900, W. N. Suksdorf 60, Wash. Ured. 718; Yakima, July 18, 1919, F. D. Heald, Herb. W.S.C. 624.

*Agropyron* sp. Bingen, May 27, 1896, W. N. Suksdorf 531, Wash. Ured. 680.

*Bromus carinatus* Hook. & Arn. Bingen, Aug. 27, 1900, W. N. Suksdorf 587, Wash. Ured. 702; Kent, Aug. 20, 1912, E. Bartholomew, N. Am. Ured. 1128, Arth. Herb.; Puyallup, Oct. 6, 1918, A. Frank, Wash. Ured. 422; Hoquiam, July 2, 1920, C. R. Stillinger, Arth. Herb.; Olympia, July 28, 1920, C. R. Stillinger, Arth. Herb.; Rolling Bay, Oct. 9, 1921, Wash. Ured. 204; Winslow, Oct. 9, 1921, Wash. Ured. 208; Georgetown, Nov. 10, 1921, Wash. Ured. 227; Snoqualmie Falls, Dec. 10, 1921, Wash. Ured. 284.

*Bromus marginatus* Nees. Puyallup, Aug. 29, 1919, A. Frank, Wash. Ured. 426; Seattle, May 13, 1920, W. E. Flowers 6330, Wash. Ured. 2594.

*Bromus polyanthus* Schribn. Puyallup, Aug. 23, 1909, E. Bartholomew, Barth. Fungi Columb. 3165, Arth. Herb.

*Bromus sitchensis* Bong. Kent, Aug. 20, 1912, E. Bartholomew, Barth. N. Am. Ured. 1330, Fungi Columb. 445, Arth. Herb.

*Bromus subvelutinus* Shear. Bremerton, July 31, 1912, E. Bartholomew 4800, Arth. Herb.

*Bromus* sp. Falcon Valley, July 26, 1886, W. N. Suksdorf 33, Wash. Ured. 506; Bingen, May 25, 1902, W. N. Suksdorf 794, Wash. Ured. 726; Georgetown, Nov. 10, 1921, Wash. Ured. 227.

*Elymus arenarius* L. Rolling Bay, Oct. 9, 1921, Wash. Ured. 206; Winslow, Oct. 10, 1921, Wash. Ured. 205; Bothell, Nov. 12, 1921, Wash. Ured. 261; Aberdeen, Sept. 6, 1922, Wash. Ured. 1039.

*Elymus condensatus* Presl. Wenatchee, July 15, 1912, E. Bartholomew, Barth. Fungi Columb. 4458, N. Am. Ured. 1341, Arth. Herb.; Yakima, July 7, 1915, F. D. Heald, Herb. W.S.C. 140, Wash. Ured. 2742; Pullman, Sept. 6, 1916, D. C. George, Herb. W.S.C. 426, Wash. Ured. 1297; Kennewick, June 2, 1919, C. R. Stillinger, Wash. Ured. 2724; Colton, Aug. 20, 1919, Wash. Ured. 342; Waitsburg, Aug., 1919, Wash. Ured. 343.

*Elymus glaucus* Buckl. Skamania Co., Sept. 13, 1902, W. N.

Suksdorf 793, Wash. Ured. 725; near Trout Lake, Klickitat Co., Sept. 13, 1902, W. N. Suksdorf 792, Arth. Herb.; Falcon Valley, July 17, 1905, W. N. Suksdorf 994, Wash. Ured. 752; Hillyard, Sept. 20, 1914, W. E. Flowers 6002, Wash. Ured. 2501; Langley, Sept., 1921, J. M. Grant, Wash. Ured. 303; Markham, Sept. 6, 1922, Wash. Ured. 1038.

*Elymus voncouverensis* Vasey. Tacoma, June 25, 1920, C. R. Stillinger 1044, Arth. Herb.

*Hordeum nodosum* L. Hoquiam, Oct., 1922, E. Bethel.

*Puccinia clematidis* as here used is in accordance with the arrangement which Arthur and Fromme have made in the North American Flora 7:333, 1920. This species shows a number of quite sharply differentiated races, each of which acts quite differently toward the hosts of the others, showing biologic differences; but as far as at present known, there is little or no morphological difference. Unless further cultural data show that distinct morphological differences are connected with these biological differences it is well to consider the different forms as races rather than as independent species. Some authors prefer to take the latter view, designating the rust found on *Agropyron* as *P. agropyri* Ellis & Ev., that on *Bromus* as *P. tomipura* Trel., *P. alternans* Arth. or *P. bromina* Eriks.; that on *Elymus* as *P. elymi* Lagerh.; that on *Poa* as *P. cinerea* Arth., et al. The common leaf rust of wheat (*P. triticina* Eriks.) is cited above as a synonym and probably is, but it would seem to serve the purposes of this paper best to list the collections on wheat separately (Cf. 167).

#### 79. *Puccinia clintonii* Peck

Ann. Rept. N. Y. State Mus. 28:61, 1876.

*Micropuccinia clintonii* (Peck) Arth. & Jackson; N. Am. Flora 7:564, 1922.

On SCROPHULARIACEAE: 0, III.

*Pedicularis groenlandica* Retz. Locke, July 19, 1917, W. E. Flowers 6022, Wash. Ured. 2520.

#### 80. *Puccinia cnici* Mart.

Fl. Mosq. 226, 1817.

*Puccinia cirsii-lanceolati* Schroet., Cohn, Krypt. Fl. Schl. 3:317, 1887.

*Dicaeoma cnici* (H. Mart.) Arth. Résult Sci. Congr. Bot. Vienne 344, 1906; N. Am. Flora 7:435, 1921.

On COMPOSITAE: 0, I, II, III. Autoecious.

*Cirsium lanceolatum* (L.) Hill. Bingen, May 22, 1894, W. N. Suksdorf 390, Wash. Ured. 641; Bainbridge Is., July 17, 1909, F. Bartholomew, Barth. Fungi Columb. 3169, Arth. Herb.; Seattle, Apr. 8, 1910, T. C. Frye, Arth. Herb., Wash. Ured. 68; Manette, July 20,

1912, E. Bartholomew 4751, Barth. N. Am. Ured. 832, Arth. Herb.; Bremerton, E. Bartholomew, Barth. N. Am. Ured. 831, Arth. Herb.; Pullman, July 20, 1915, D. C. George, Herb. W.S.C. 119, Wash. Ured. 2720; Yakima, Sept. 10, 1915, Wash. Ured. 40; Seattle, Oct. 4, 1917, Wash. Ured. 81; Winslow, May, 1920, Wash. Ured. 159; Kirkland, July 10, 1920, C. R. Stillinger 704, Wash. Ured. 812; Fir, Aug. 17, 1920, F. Renner, Arth. Herb.; Monroe, Sept. 17, 1921, G. L. Zundel, Wash. Ured. 1138; Renton, Oct. 3, 1921, Wash. Ured. 1070; Bothell, Nov. 12, 1921, Wash. Ured. 247; Medina, Nov. 12, 1921, Wash. Ured. 239; Snoqualmie Falls, Dec. 10, 1921, Wash. Ured. 283; Forks, June 28, 1922, Wash. Ured. 987; Olympia, July 21, 1922, Wash. Ured. 1270; Puget, July 21, 1922, Wash. Ured. 994; Boston Harbor, July 21, 1922, Wash. Ured. 995; Langley, Feb. 10, 1923, J. M. Grant, Wash. Ured. 1813; Edmonds, Apr. 15, 1923, A. J. Seltzer, Wash. Ured. 1800; Gig Harbor, June 9, 1923, A. J. Seltzer, Wash. Ured. 1811.

### 81. *Puccinia columbiensis* Ell. & Ev.

Proc. Acad. Sci. Phila. 1893:153, 1893.

*Puccinia bicolor* Ell. & Ev. Bull. Torrey Club 27:572, 1900.

*Puccinia nabali* Arth. Bull. Torrey Club 37:571, 1910.

*Micropuccinia columbiensis* (Ellis & Ev.) Arth. & Jackson, Bull. Torrey Club 48:40, 1921; N. Am. Flora 7:585, 1922.

On COMPOSITAE: 0 (?), III.

*Hieracium scouleri* Hook. Waitsburg, May 7, 1900, R. M. Horner, E. & E. Fungi Columb. 1570, Arth. Herb. (type collection).

*Hieracium* sp. Chiquash Mt., July 19, 1894, W. N. Suksdorf 384, Arth. Herb., Wash. Ured. 633.

### 82. *Puccinia comandrae* Peck

Bull. Torrey Club 11:49, 1884.

*Micropuccinia comandrae* (Peck) Arth. & Jackson, Bull. Torrey Club 48:40, 1921; N. Am. Flora 7:553, 1922.

On SANTALACEAE: 0, III.

*Comandra pallida* DC. Columbus, June 10, 1886, W. N. Suksdorf 341; Locke, July 19, 1912, W. E. Flowers 6020, Wash. Ured. 2519.

*Comandra umbellata* (L.) Nutt. Falcon Valley, Sept., 1894, W. N. Suksdorf 414, Wash. Ured. 663.

### 83. *Puccinia commutata* Sydow

Monog. Ured. 1:201, 1902.

*Allodus commutata* (Sydow) Arth. Result. Sci. Congr. Bot. Vienne 345, 1906; N. Am. Flora 7:473, 1921.

On VALERIANACEAE: 0, I, III.

*Valerianella congesta* Lindl. Husum, Apr. 30, 1884, W. N. Suks-

dorf 161, Arth. Herb., Wash. Ured. 531; Bingen, May 5, 1894, W. N. Suksdorf 167, Wash. Ured. 1186.

#### 84. *Puccinia consimilis* Ellis & Ev.

Jour. Myc. 6:120, 1891.  
*Allodus consimilis* (Ellis & Ev.) Orton, Mem. N. Y. Bot. Gard. 6:187, 1916;  
N. Am. Flora 7:459, 1921.

On CRUCIFERAE: 0, I, III. Autoecious

*Sisymbrium linifolium* Nutt. Reported for Washington by E. W. D. Holway in his N. Am. Ured. 1:44, 1906, but the writer was unable to obtain the data for this collection.

Prof. C. O. Rosendahl very kindly looked over Holway's collection but could find no specimens of this species from the state of Washington. It appears that most of the specimens of this species in the Holway herbarium were collected in Montana and Wyoming.

#### 85. *Puccinia crepidis-montanae* (Syd.) Magnus

Beitr. Krypt. Schweiz. 2:212, 1904.  
*Aecidium crepidis-montanae* Sydow, Oesterr. Bot. Zeits. 51:29, 1901.  
*Dicaeoma crepidis-montanae* (Syd.) Arth., N. Am. Flora 7:439, 1921.

On COMPOSITAE: 0, I, II, III. Autoecious.

*Crepis barbigera* Leib. Wenatchee, July 15, 1912, E. Bartholomew, Barth. Fungi Columb. 4459, Arth. Herb.; Spokane, June 24, 1913, G. Turreson, Arth. Herb.

*Crepis gracilis* (Eaton) Rydb. Waitsburg, May 7, 1900, R. M. Horner 1436, Herb. W.S.C.

#### 86. *Puccinia cryptanthæ* Dietel & Holway

Erythea 1:249, 1893.  
*Dicaeoma* (?) *cryptanthæ* (Diet. & Holw.) Arth., N. Am. Flora 7:404, 1920.

On BORAGINACEAE: II, III. (0, I unknown).

*Cryptantha torreyana* (Gray) Greene. Falcon Valley, July 19, 1886, W. N. Suksdorf 263, Wash. Ured. 584.

#### 87. *Puccinia curtipes* Howe

Bull. Torrey Club 5:3, 1874.  
*Puccinia striata* Cooke, Grevillea 7:3, 1878.  
*Puccinia saxifragæ curtipes* Dietel, Ber. Deuts. Bot. Ges. 9:40, 1891.  
*Puccinia striatospora* Peck, Mycologia 5:71, 1913.  
*Micropuccinia curtipes* (Howe) Arth. & Jackson, Bull. Torrey Club 48:42, 1921; N. Am. Flora 7:536, 1922.

On SAXIFRAGACEAE: 0, III.

*Heuchera glabella* T. and G. Pullman, June 28, 1898, L. D. Malone; also same date, C. V. Piper 607, Herb. W.S.C., June 28, 1916, B. F. Dana, Herb. W.S.C. 310, Wash. Ured. 2748; Waitsburg, May,

1900, R. M. Horner 1431, Arth. Herb., Herb. W.S.C., E. & E. Fungi Columb. 1571.

*Saxifraga oregana* Howell. Falcon Valley, June 23, 1911, W. N. Suksdorf 1094, Wash. Ured. 1258.

This species should not be confused with *P. heucherae* found in Washington on the same hosts. They both belong to the micro-type. The teliospores of the rust under consideration are strongly striate and mostly ellipsoid, while in *P. heucherae* they are smooth with only occasional striae and mostly oblong in shape.

### 88. *Puccinia cyani* (Schleich.) Pass.

Rabh. Fungi Eur. 1767, 1873.

*Uredo cyani* Schleich. (Pl. Crypt. Helv. 95, hyponym, 1805); DC. Fl. Fr. 6:74, 1815.

*Bullaria cyani* (Schleich.) Arth. Result. Sci. Congr. Bot. Vienne 346, 1906; N. Am. Flora 7:511, 1922.

On COMPOSITAE: 0, II, III.

*Centaurea cyanus* L. Bingen, July 1, 1912, W. N. Suksdorf 1096, Wash. Ured. 1203; Pullman, July 18, 1921, C. S. Parker, W.S. C. 790, Wash. Ured. 2783; Seattle, Apr. 30, 1923, V. Stedman, Wash. Ured. 1801.

### 89. *Puccinia dichelostemmae* Diet. & Holw.

*Erythea* 3:78, 1895.

*Allodus dichelostemmae* (D. & H.) Orton, Mem. N. Y. Bot. Gard. 6:183, 1916; N. Am. Flora 7:456, 1921.

On LILIACEAE: 0, I, III. Autoecious.

*Hookera douglasii* (Wats.) Piper. Pullman, May 22, 1894, C. V. Piper 256, Wash. Ured. 340; also June 11, 1915, F. D. Heald and D. C. George, Herb. W.S.C. 33, Wash. Ured. 2705.

*Hookera pulchella* Salisb. Bingen (type region), May 22, 1894, W. N. Suksdorf 389, Barth. N. Am. Ured. 139, Arth. Herb., Wash. Ured. 639.

"This species may be separated from all other species of *Puccinia* occurring on Liliaceae by the very large, broad teliospores (38-45 by 43-58  $\mu$ ) having smooth walls 5-7  $\mu$  thick." Jackson.

### 90. *Puccinia douglasii* Ellis & Ev.

Proc. Phil. Acad. 1893:152, 1893.

*Puccinia richardsonii* Sydow, Monog. Ured. 1:317, 1902.

*Allodus douglasii* (Ellis & Ev.) Orton, Mem. N. Y. Bot. Gard. 6:198, 1916; N. Am. Flora 7:469, 1921.

On POLEMONIACEAE: 0, I, III. Autoecious.

*Phlox diffusa* Benth. Mt. Adams, Aug. 31, 1894, W. N. Suksdorf 376, Arth. Herb., Barth. N. Am. Ured. 154, Wash. Ured. 625.



*Phlox rigida* Benth. Spokane, June 9, 1919, J. R. Weir 10250, Arth. Herb.; also June 9, 1919, W. E. Flowers 6038, Wash. Ured. 1235.

**91. *Puccinia dracunculi* (Thüm.) comb. nov.**

*Aecidium dracunculi* Thüm., Bull. Soc. Nat. Moscow, 58:212, 1878. Not

*Puccinia dracunculi* Auersw. Herb. Viv. Myc. 1488, 1850.

*Puccinia universalis* Arth. Jour. Myc. 14:21, 1908.

*Dicaeoma dracunculi* (Thüm.) Arth. & Kern, N. Am. Flora 6:360, 1920.

On COMPOSITAE: 0, I, Heteroecious.

*Artemisia ludoviciana* Nutt. Spokane, July 4, 1914, W. E. Flowers 6029, Wash. Ured. 2527.

On CYPERACEAE: II, III.

*Carex rossii* Boott. Falcon Valley, Sept. 28, 1898, W. N. Suksdorf 552, Wash. Ured. 698.

**92. *Puccinia effusa* Dietel & Holway**

*Erythraea* 3:81, 1893.

*Allodus effusa* (D. & H.) Arth. Result. Sci. Congr. Bot. Vienne 345, 1906; N. Am. Flora 7:460, 1921.

On VIOLACEAE: 0, I, III. Autoecious.

*Viola nuttallii praemorsa* (Dougl.) Wats. Falcon Valley, Sept. 2, 1894, W. N. Suksdorf 407, Arth. Herb., Barth. N. Am. Ured. 1438, Wash. Ured. 657.

**93. *Puccinia ellisii* De-Toni**

Sacc. Syll. Fung. 7:651, 1888.

*Puccinia angelicae* Ellis & Ev., Bull. Washb. Lab. Nat. Hist. 1:3, 1884 (Not *P. angelicae* Fockl. 1870).

*Puccinia bakeriana* Arth. Bull. Torrey Club 31:3, 1904.

*Bullaria ellisii* (De-Toni) Arth. & Mains, N. Am. Flora 7:491, 1922.

On UMBELLIFERAE: II, III. Autoecious.

*Angelica genuflexa* Nutt. Falcon Valley, Aug., 1883, W. N. Suksdorf, Ellis N. Am. Fungi 1449, Arth. Herb.

*P. angelicae* Fockl. also occurs on the same host as this species but the teliospores are smooth, while in *P. ellisii* they are verrucose.

**94. *Puccinia epilobii-tetragoni* (DC.) Wint.**

Rabenh. Krypt. Fl., 1:214, 1881.

*Uredo vagans epilobii-tetragoni* DC., Fl. Fr. 2:228, 1805.

*Puccinia gayophyti* Billings, in King's Geol. Expl. 40th Par. 5:414, 1871.

*Puccinia oenotherae* Vize, Grevillea 5:109, 1877.

*Puccinia boisduvaliae* Peck, Bot. Gaz. 7:45, 1882.

*Puccinia clarkiae* Peck, Bull. Torrey Club 11:49, 1884.

*Puccinia glabella* Holw. N. Am. Ured. 1:76, 1907.

*Dicaeoma epilobii-tetragoni* (DC.) Arth. N. Am. Flora 7:394, 1920.

On ONAGRACEAE: 0, II, III. Autoecious.

*Boisduvalia densiflora* (Lindl.) Wats. Pullman, Aug., 1893, C.

V. Piper 135, Wash. Ured. 2886; Spangle, June 24, 1898, C. V. Piper 393, Wash. Ured. 1331.

*Clarkia pulchella* Pursh. Pullman, July 28, 1894, C. V. Piper 178, Wash. Ured. 2804; Spokane, June 8, 1914, W. E. Flowers 6147, Wash. Ured. 1240.

*Clarkia rhomboidea* Dougl. Falcon Valley, June 23, 1893, W. N. Suksdorf 240, Arth. Herb., Wash. Ured. 566; Bingen, May 5, 1894, W. N. Suksdorf 240b, Arth. Herb., Ellis N. Am. Ured. 159; Fort Lawton, May 26, 1922, Wash. Ured. 1266.

*Epilobium adenocaulon* Haussk. Falcon Valley, May 19, 1884, W. N. Suksdorf 163, Arth. Herb., Wash. Ured. 533; Bingen, May 27, 1902, W. N. Suksdorf 799, Wash. Ured. 728; Parker Lake, May 23, 1915, W. E. Flowers 6310, Wash. Ured. 1243.

*Epilobium alpinum* L. Bingen, Sept. 15, 1898, W. N. Suksdorf 547, Wash. Ured. 693.

*Epilobium americanum* Haussk. Oakesdale, June 13, 1919, C. R. Stillinger, Arth. Herb.

*Epilobium paniculatum* Nutt. Falcon Valley, July 26, 1883, W. N. Suksdorf 25, Wash. Ured. 503; Almota, Apr. 18, 1894, C. V. Piper 2, Arth. Herb., Wash. Ured. 2891; Pullman, June 6, 1894, C. V. Piper 502, Wash. Ured. 2897; Bingen, May 10, 1895, W. N. Suksdorf 1081, Wash. Ured. 778; Blue Mts., Columbia Co., July 17, 1897, R. M. Horner 1199 and 1200, Herb. W.S.C.; Bremerton, Aug. 30, 1912, E. Bartholomew, Barth. N. Am. Ured. 1148, Arth. Herb.; Kirkland, July 10, 1920, C. R. Stillinger 705, Wash. Ured. 813; Palouse, Sept. 15, 1920, G. B. Posey and C. R. Stillinger 776, Wash. Ured. 1092.

*Epilobium* sp. Glacier, July 8, 1920, C. R. Stillinger 642; Pullman, Aug. 23, 1921, B. F. Dana, Herb. W.S.C. 907, Wash. Ured. 2798.

*Gayophytum caesium* T. & G. Falcon Valley, June 23, 1893, W. N. Suksdorf 239, Wash. Ured. 565.

*Gayophytum ramosissimum* T. & G. Spokane, May 19, 1913, W. E. Flowers 6126, Wash. Ured. 1237; Locke, June 21, 1915, W. E. Flowers 6281, Wash. Ured. 2579.

*Gayophytum* sp. Mt. Adams, Sept. 18, 1894, W. N. Suksdorf 1080, Wash. Ured. 777.

*Godetia epilobioides* Wats. Bingen, May 12, 1894, W. N. Suksdorf 332, Wash. Ured. 607.

*Godetia* sp. Bingen, June 2, 1894, W. N. Suksdorf 1074, Wash. Ured. 772.

*Oenothera strigosa* Rydb. Medical Lake, July 4, 1906, W. E. Flowers 6025, Wash. Ured. 2523.

*Oenothera* sp. Spangle, June 22, 1904, W. N. Suksdorf 977, Wash. Ured. 742; Spokane, June 8, 1910, W. E. Flowers 6182, Wash. Ured. 2574.

*Sphaerostigma andinum* (Nutt.) Walp. Coulee City, June 1, 1902, C. V. Piper 800, Arth. Herb.

*Sphaerostigma boothii* (Dougl.) Walp. Rock Island, July, 1893, Sandberg and Leiber, Arth. Herb.

*Sphaerostigma contortum* (Dougl.) Walp. Yakima, May 27, 1892, C. V. Piper 807, Arth. Herb.

*Sphaerostigma* sp. Blue Mts., Columbia Co., July 11, 1897, R. M. Horner 1198, Herb. W.S.C.

This species includes all the long-cycled autoecious rusts found on the Onagraceae.

#### 95. *Puccinia epiphylla* (L.) Wettst.

Verh. Zool.-Bot. Ges. Wein 35:541, 1885.

*Lycoperdon epiphyllum* L. Sp. Pl. 1185, 1753.

*Aecidium tussilaginis* Pers. in Gmel. Syst. Nat. 2:1473, 1791.

*Puccinia poarum* Niels. Bot. Tidsskr. III. 2:34, 1877.

*Dicaeoma epiphyllum* (L.) Kuntze, Rev. Gen. 3:468, 1898; N. Am. Flora 7:327, 1920.

On POACEAE: II, III. (0, I on Compositae).

*Poa compressa* L. Marysville, July 18, 1920, C. R. Stillinger, Arth. Herb.; Ilwaco, Oct. 16, 1922, E. Bethel, Wash. Ured. 1072.

*Poa pratensis* L. Bingen, May 7, 1894, W. N. Suksdorf 397, Wash. Ured. 650; Bainbridge Island, Aug. 4, 1909, E. Bartholomew, Barth. Fungi Columb. 3175, Arth. Herb.; Duckabush River, Jefferson Co., Aug. 7, 1912, E. Bartholomew, Barth. N. Am. Ured. 761, Arth. Herb.; Pullman, June 20, 1915, H. M. Woolman, Herb. W.S.C. 49, Wash. Ured. 2711; Hoquiam, July 2, 1920, C. R. Stillinger and G. B. Posey, Arth. Herb., Wash. Ured. 1097; Winslow, Nov. 2, 1921, Wash. Ured. 267; Bothell, Dec. 10, 1921, Wash. Ured. 273; Snoqualmie Falls, Dec. 10, 1921, Wash. Ured. 280.

*Poa trivialis* L. Hoquiam, June 25, 1920, C. R. Stillinger and G. B. Posey, Arth. Herb.

*Poa vaseyochloa* Scribn. Bingen, May 11, 1894, W. N. Suksdorf 398, Arth. Herb., Wash. Ured. 651.

#### 96. *Puccinia expansa* Link

in Willd., Sp. Pl. 6:75, 1825.

*Micropuccinia expansa* (Link) Arth. & Jackson, Bull. Torrey Club 48:40, 1921; N. Am. Flora 7:583, 1922.

On COMPOSITAE: 0, III.

*Senecio* sp. Spokane, May 11, 1914, W. E. Flowers 6329, Wash. Ured. 1246.

**97. *Puccinia gemella* Diet. & Holw.**

Sydow Monog. Ured. 1:541, 1903.

*Micropuccinia gamella* (Diet. & Holw.) Arth. & Jackson, N. Am. Flora 7:529, 1922.

On RANUNCULACEAE: 0, III.

*Caltha biflora* DC. Granite, July 17, 1920, W. E. Morgan, Arth. Herb.

*Caltha leptosepala* DC. Mt. Rainier, Aug. 23, 1901, E. W. D. Holway (type material), Arth. Herb.

There are three rusts found on *Caltha* in Washington, *P. areolata*, a eu-type, *P. treleasiana*, a micro-type with rough teliospores, and *P. gemella*, a micro-type with smooth teliospores.

**98. *Puccinia gentianae* (Strauss) Link**

in Willd. Sp. Pl. 6:73, 1825.

*Uredo gentianae* Strauss, Ann. Wett. Ges. 2:102, 1810.

*Dicaeoma gentianae* (Strauss) Kuntze, Rev. Gen. 3:468, 1898; N. Am. Flora 7:400, 1920.

On GENTIANACEAE: 0, I, II, III.

*Gentiana oregana* Engelm. Pullman, Sept. 23, 1893, C. V. Piper 127, Arth. Herb., Wash. Ured. 2889.

**99. *Puccinia gigantea* P. Karst.**

Bidr. Finl. Nat. Folk 31:42, 1879.

*Puccinia annulata* Ellis & Ev., Bull. Torrey Club 27:60, 1900.

*Micropuccinia gigantea* (P. Karst.) Arth. & Jackson, N. Am. Flora 7:549, 1922.

On ONAGRACEAE: 0, III.

*Epilobium angustifolium* L. Hillyard, July 20, 1914, W. E. Flowers 6499, Wash. Ured. 2602.

**100. *Puccinia gilliae* Hark.**

Bull. Calif. Acad. 1:34, 1884.

*Dicaeoma gilliae* (Hark.) Kuntze, Rev. Gen. 3:469, 1898; N. Am. Flora 7:403, 1920.

On POLEMONIACEAE: II, III (0, I unknown).

*Collomia grandiflora* Dougl. Falcon Valley, July 10, 1900, W. N. Suksdorf 598, N. Am. Ured. 1650, Arth. Herb., Wash. Ured. 711.

This rust should not be confused with *P. plumbaria*. The latter does not have uredinia, the telia are long, covered by the cinereous epidermis and the teliospores are finely and closely verrucose. *P. Gilliae* on the other hand has uredinia, the telia are early naked and the teliospores are smooth.

**101. *Puccinia glumarum* (Schmidt) Erikss. & Henn.**

Zeits. Pflanzenkr. 4:197, 1894.

*Uredo glumarum* Schmidt. Nat. Landw. Schädli. Pilze. 1819; Fries Om Band och Rost 23:1821; Allg. Oekon. Fl. 1:27, 1827.

*Puccinia neglecta* West. Bull. Soc. Bot. Belg. 2:248, 1863.

*Dicaeoma glumarum* (Schmidt) Arth. & From., N. Am. Flora 7:338, 1920.

On POACEAE: II, III (0, I unknown).

*Aegilops cylindrica* Host. Pullman, May 5, 1921, G. L. Zundel, Herb. W.S.C. 784, Wash. Ured. 2782.

*Agropyron cristatum* Beauv. Pullman, Aug. 29, 1916, C. W. Hungerford 15, Wash. Ured. 1347.

*Agropyron* sp. Pullman, July 19, 1916, B. F. Dana, Herb. W.S. C. 391, Wash. Ured. 2757.

*Bromus hookeianus* (Thurb.) Shear. Everett, July, 1892, C. V. Piper 206, Arth. Herb.

*Bromus marginatus* Nees. Pullman, July 14, 1915, H. B. Humphrey & A. G. Johnson, Arth. Herb.; also Aug. 29, 1916, C. W. Hungerford 14, Wash. Ured. 1349; Burlington, Sept. 2, 1916, C. W. Hungerford 28, Wash. Ured. 1350.

*Bromus pacificus* Shear. Friday Harbor, June 15, 1916, H. B. Humphrey, Arth. Herb.

*Bromus sitchensis* Bong. Bellingham, Sept. 1, 1916, C. W. Hungerford 26, Wash. Ured. 1351.

*Bromus* sp. Waitsburg, July 22, 1918, Wash. Ured. 127.

*Elymus canadensis* L. Pullman, July 26, 1915, E. G. Schaper & H. B. Humphrey, Arth. Herb.

*Elymus condensatus* Presl. Rolling Bay, June 2, 1919, Wash. Ured. 124; Seattle, Aug., 1919, Wash. Ured. 115; Pullman, Aug. 12, 1921, C. S. Parker, Herb. W.S.C. 900, Wash. Ured. 2795.

*Elymus glaucus* Buckl. Seattle, June, 1892, C. V. Piper 41 (Phytopath. 7:142, 1917); Mt. Vernon, June 14, 1916, H. B. Humphrey, Arth. Herb.; Friday Harbor, June 16, 1916, H. B. Humphrey, Arth. Herb.; Marysville, June 20, 1920, C. R. Stillinger 1203, Arth. Herb.; Olympia, July, 1920, C. R. Stillinger 1040, Arth. Herb.; Hoquiam, July 2, 1920, C. R. Stillinger 798, Arth. Herb., Wash. Ured. 1096; LaConner, Aug., 1921, Wash. Ured. 199; Pullman, Nov. 14, 1921, C. W. Hungerford, Wash. Ured. 1348; Nisqually River, Thurston Co., July 25, 1922, Wash. Ured. 1209.

*Hordeum jubatum* L. Selah, June 17, 1916, H. B. Humphrey, Arth. Herb.; Pullman, Aug. 29, 1916, C. W. Hungerford 16, Wash. Ured. 1352; Oakesdale, Sept. 25, 1916, C. W. Hungerford 42, Wash. Ured. 1353.

*Hordeum nodosum* L. Milltown, June 27, 1919, G. L. Zundei, Wash. Ured. 1271; Marysville, July 10, 1920, Wash. Ured. 360; Rolling Bay, July 25, 1920, Wash. Ured. 122; Pullman, Nov. 14, 1921, C. W. Hungerford, Wash. Ured. 1354; Hoquiam, Oct. 18, 1922, E. Bethel, Wash. Ured. 1073.

*Sitaniom jubatum* Smith. Oakesdale, June 3, 1919, C. R. Stillinger, Arth. Herb.

*Triticum vulgare* Vill. Bellingham, June 3, 1915, F. K. Raun & A. G. Johnson, Arth. Herb.; Yakima, July 10, 1915, Arth. Herb., Wash. Ured. 244; Pullman, July 17, 1915, F. D. Heald, Herb. W.S.C. 105, Wash. Ured. 2717. (On Aug. 30, 1916, C. W. Hungerford made the following collections at Pullman on various varieties of wheat: On Columbian, Hungerford 18, Wash. Ured. 1355; on Little Club Wheat, Hungerford 20, Wash. Ured. 1356; on Alaska, Hungerford 21, Wash. Ured. 1357; on Bearded Red Fife, Hungerford 22, Wash. Ured. 1358; on Polish Wheat, Hungerford 23, Wash. Ured. 1359.); Mt. Vernon, June 14, 1916, C. W. Hungerford 32A, Wash. Ured. 1360; Freeman, June 18, 1916, H. B. Humphrey, Arth. Herb.; Oakesdale, July, 1918, Wash. Ured. 123; Lacrosse, June 14, 1919, C. R. Stillinger, Arth. Herb.; Pleasant Prairie, June 29, 1919, F. D. Heald, Herb. W.S.C. 652, Wash. Ured. 1299; Snohomish, Aug. 15, 1919, E. W. Knight, Wash. Ured. 1189; Walla Walla, May 24, 1921, B. F. Dana, Herb. W.S.C. 854, Wash. Ured. 2791; Dixie, June 24, 1921, B. F. Dana, Herb. W.S.C. 854b, Wash. Ured. 1300; Kirkland, Nov. 12, 1921, Wash. Ured. 2661.

## 102. *Puccinia graminis* Pers.

Neues Mag. Bot. 1:119, 1794.

*Lycoperdon poculiforme* Jacq. Coll. Austr. 1:122, 1786.

*Accidium berberidis* Pers. in J. F. Gmel. Syst. Nat. 2:1473, 1791.

*Puccinia phlei-pratensis* Erikss. & Henn. Zeit. f. Pflanzenkr. 4:140, 1894.

*Dicaeoma poculiforme* (Jacq.) Kuntze, Rev. Gen. 3:466, 1898; N. Am. Flora 7:295, 1920.

On BERBERIDACEAE: 0, I. Heteroecious.

*Berberis vulgaris* L. Pullman, July 11, 1899, R. M. Horner 1181, Herb. W.S.C.; also during 1916 and 1917 by F. D. Heald; also Oct. 3, 1917, C. W. Hungerford, Wash. Ured. 1346; Spokane, July 3, 1914, W. E. Flowers 6028, Wash. Ured. 2526; Mt. Vernon, June 22, 1922, B. F. Dana, Herb. W.S.C. 3488.

On POACEAE: II, III.

*Arrhenatherum elatius* (L.) Beauv. Pullman, Oct. 20, 1898, L. D. Malone, Arth. Herb.

*Avena fatua* L. Pullman, Oct. 23, 1916, E. C. Stakman, Arth. Herb.

*Avena fatua glabrata* Peterm. Olympic Marsh, Sept. 2, 1922, C. H. Bergstrom, Wash. Ured. 1035; Mt. Vernon, Sept. 2, 1922, C. H. Bergstrom, Wash. Ured. 1034.

*Avena sativa* L. Oak Harbor, Aug. 30, 1919, Wash. Ured. 346; Puyallup, Sept. 23, 1919, A. Frank, Wash. Ured. 420; Bothell, Oct. 15, 1921, Wash. Ured. 255; Olympia, Aug. 20, 1922, Wash. Ured. 349; Montesano, Aug. 24, 1922, Wash. Ured. 1028.

*Bromus tectorum nudum* Mert. & Koch. Pullman, Oct. 26, 1916, E. C. Stakman, Arth. Herb.

*Cinna latifolia* (Trev.) Griseb. Winslow, Oct. 10, 1921, Wash. Ured. 207.

*Dactylis glomerata* L. Winslow, June 2, 1919, Wash. Ured. 356.

*Elymus canadensis* L. Pullman, Oct. 23, 1916, E. C. Stakman, Arth. Herb.

*Elymus condensatus* Presl. Nespelem, Sept. 20, 1915, B. F. Dana, Herb. W.S.C. 371, Wash. Ured. 2756; Ritzville, Oct. 27, 1916, E. C. Stakman, Arth. Herb.; Colton, Aug. 20, 1919, Wash. Ured. 357; Pullman, Aug. 12, 1921, C. S. Parker, Wash. Ured. 2796.

*Elymus glaucus* Buckl. Pullman, Oct. 23, 1916, E. C. Stakman, Arth. Herb.

*Elymus macounii* Vasey. Ellensburg, Oct. 26, 1916, E. C. Stakman, Arth. Herb.

*Elymus triticoides* Buckl. Pasco, Oct. 7, 1916, E. C. Stakman, Arth. Herb.

*Elymus* sp. Pullman, Oct. 26, 1921, F. D. Heald, Herb. W.S.C. 753, Wash. Ured. 2773.

*Festuca elatior* L. Pullman, Oct. 22, 1916, E. C. Stakman, Arth. Herb.

*Hordeum distichon palmella zeocriton* L. (Rice- or Fan-barley). Pullman, Aug. 30, 1916, F. D. Heald and D. C. George, Herb. W.S.C. 410, Wash. Ured. 1302.

*Hordeum jubatum* L. Pullman, Oct. 22, 1916, E. C. Stakman, Arth. Herb.; also Nov. 14, 1918, C. W. Hungerford, Wash. Ured. 1345.

*Hordeum nodosum* L. Pullman, Oct. 23, 1916, E. C. Stakman, Arth. Herb.

*Phleum pratense* L. Prosser, Aug. 20, 1915, F. D. Heald, Herb. W.S.C. 217, Wash. Ured. 2737; Puyallup, Aug. 1, 1916, A. Frank, Wash. Ured. 425; Waitsburg, July 25, 1919, Wash. Ured. 345; Oak

Harbor, Aug. 20, 1919, Wash. Ured. 363; Olympia, June 26, 1920, C. R. Stillinger 714, Wash. Ured. 820; Pullman, Nov. 7, 1917, C. W. Hungerford, Wash. Ured. 1344; also Oct. 26, 1920, F. D. Heald, Herb. W.S.C. 752, Wash. Ured. 2772; Medina, Nov. 12, 1921, Wash. Ured. 238; Nisqually River, Thurston Co., July 25, 1922, Wash. Ured. 1208; Bellingham, Aug., 1922, E. Bethel; Westport, Sept. 6, 1922, Wash. Ured. 1040; Markham, Sept. 6, 1922, Wash. Ured. 1041; Aberdeen, Sept. 7, 1922, Wash. Ured. 1044; Montesano, Sept. 7, 1922, Wash. Ured. 1043; Port Ludlow, Sept. 12, 1922, Wash. Ured. 1272; Port Townsend, Sept. 14, 1922, Wash. Ured. 1053.

*Triticum compactum* Host. Pullman, Oct. 22, 1916, E. C. Stakman, Arth. Herb.

*Triticum vulgare* Vill. Falcon Valley, Sept. 21, 1894, W. N. Suksdorf 399, Arth. Herb., Wash. Ured. 652; Yakima, July 7, 1915, F. D. Heald, Herb. W.S.C. 135, Wash. Ured. 2721; Rosalia, July 28, 1919, Wash. Ured. 147; Colton, Aug. 21, 1919, Wash. Ured. 361; Oak Harbor, Aug. 26, 1919, Wash. Ured. 129; Olympia, Sept. 30, 1919, Wash. Ured. 316; Kirkland, Nov. 12, 1921, Wash. Ured. 245; Snoqualmie Falls, Dec. 10, 1921, Wash. Ured. 272.

### 103. *Puccinia granulispora* Ellis & Gall.

Bull. Torrey Club 22:61, 1895.

*Dicaeoma granulisporum* (Ellis & Gall.) Kuntze, Rev. Gen. 3:469, 1898; N. Am. Flora 7:375, 1920.

On LILIACEAE: O, I, II, III. Autoecious.

*Allium cernuum* Roth. Friday Harbor, June 22, 1921, G. Howard, Wash. Ured. 1223.

*Allium* sp. Cape Horn, Aug. 19, 1894, W. N. Suksdorf 391, Arth. Herb., Wash. Ured. 642; Eatonville, Aug. 28, 1901, W. N. Suksdorf, Arth. Herb.

"This species agrees in all essentials with *Nigredo* (Uromyces) *bicolor* (Ellis) Arth. except in the possession of some two-celled teliospores. The forms are separately maintained for convenience, but should eventually be united under one name." N. Am. Flora 7:375, 1920.

### 104. *Puccinia grindeliae* Peck

Bot. Gaz. 4:127, 1879.

*Puccinia solidaginis* Peck, Bull. Torrey Club 11:49, 1884.

*Puccinia bigeloviae* Ellis & Ev., N. Am. Fungi 2248, hyponym, 1889.

*Puccinia hyalomitra* Diet. & Holw., Bot. Gaz. 19:304, 1894.

*Micropuccinia grindeliae* (Peck) Arth. & Jackson, Bull. Torrey Club 48:41, 1921; N. Am. Flora 7:576, 1922.



## ON COMPOSITAE: 0, III.

*Solidago missouriensis* Gray. Fort George Wright, July 4, 1914, W. E. Flowers 6023, Wash. Ured. 2521.

**105. *Puccinia grossulariae* (Schum.) Lagerh.**

Tromsø Mus. Aarsh. 17:60, 1895.

*Aecidium grossulariae* Schum. Enum. Pl. Saell. 2:223, 1803.

*Puccinia pringsheimiana* Kleb. Zeits. Pflanzenkr. 4:194, 1894

*Puccinia magnusii* Kleb. Zeits. Pflanzenkr. 5:79, 1895.

*Puccinia albiperidia* Arth. Jour. Myc. 8:53, 1902.

*Puccinia riparia* Holway, Jour. Myc. 10:163, 1904.

*Puccinia uniporula* Orton, Mycol. 4:201, 1912.

*Dicaeoma grossulariae* (Schum.) Kern, Trans. Am. Micr. Soc. 32:64, 1913; N. Am. Flora 7:355, 1920.

## ON SAXIFRAGACEAE: 0, I. Heteroecious.

*Ribes acerifolium* Howell. Mt. Olympus, Aug., 1907, J. B. Flett & C. V. Piper, Arth. Herb.

*Ribes bracteosum* Dougl. Hoquiam, July 2, 1920, C. R. Stillinger 757, Wash. Ured. 1087; Silverton, July 5, 1920, C. R. Stillinger 736, Wash. Ured. 839; Glacier, July 8, 1920, C. R. Stillinger 722, Wash. Ured. 827.

*Ribes divaricatum* Dougl. Chehalis, May 10, 1897, Coville & N. L. Britton 1005, N. Y. Bot. Gard., Arth. Herb.; Winslow, May 25, 1920, Wash. Ured. 158; Kirkland, Nov. 12, 1921, Wash. Ured. 313; Ilwaco, Sept., 1922, E. Bethel; Falcon Valley, July 12, 1908, W. N. Suksdorf 1093, Wash. Ured. 1202.

*Ribes lacustre* (Pers.) Poir. Sullivan Lake, Sept. 25, 1915, C. R. Stillinger 155, Wash. Ured. 802; Silverton, July 7, 1920, C. R. Stillinger 728, Wash. Ured. 833.

*Ribes laxiflorum* Pursh. Ilwaco, Sept., 1922, E. Bethel.

*Ribes petiolare* Dougl. Spokane, Aug. 11, 1914, W. E. Flowers 6019, Wash. Ured. 2518.

*Ribes sanguineum* Pursh. Ilwaco, Sept., 1922, E. Bethel.

## ON CYPERACEAE: II, III.

*Carex cryptocarpa* C. Meyer. Bremerton, July 19, 1912, E. Bartholomew, Arth. Herb.; Winslow, Sept. 15, 1918, Wash. Ured. 85.

*Carex magnifica* Dewey. Bremerton, July 19, 1912, E. Bartholomew, Barth. Fungi Columb. 4461, Barth. N. Am. Ured. 1346, Arth. Herb.; Hoquiam, July 2, 1920, G. B. Poscy & C. R. Stillinger 715, Wash. Ured. 821.

*Carex nebraskensis* Dewey. Falcon Valley, Sept. 2, 1886, W. N. Suksdorf 330, Wash. Ured. 605; Uniontown, Aug. 7, 1919, B. F. Dana, Herb. W.S.C. 682, Wash. Ured. 2762.

*Carex* sp. Ilwaco, Sept., 1922, E. Bethel.

**106. *Puccinia harknessii* Vize**

*Grevillea* 7:11, 1878.

*Puccinia cladophila* Pk. Bot. Gaz. 4:127, 1879.

*Dicaeoma harknessii*; (Vize) Kuntze, Rev. Gen. 3<sup>a</sup>:469, 1898; N. Am. Flora 7:436, 1921.

On COMPOSITAE: II, III (0, I unknown).

*Ptiloria paniculata* (Nutt.) Gr. Major Creek, Sept. 16, 1886, W. N. Suksdorf 1067, Wash. Ured. 765; Yakima, Aug. 4, 1898, C. V. Piper 611, Arth. Herb.; Bingen, Oct. 12, 1898, W. N. Suksdorf 549, Wash. Ured. 695; Spokane, Sept. 8, 1902, E. W. D. Holway, Arth. Herb.

*Ptiloria tenuifolia* (Torr.) Raf. Bingen, Sept. 19, 1886, W. N. Suksdorf 53, Wash. Ured. 509; Spokane, Sept. 8, 1912, E. W. D. Holway, Fungi Columb. 4665, N. Am. Ured. 1153, Arth. Herb.

**107. *Puccinia helianthi-mollis* (Schw.) Jackson**

Brooklyn Bot. Gard. Mem. 1:250, 1918.

*Aecidium helianthi-mollis* Schw. Schrift. Nat. Ges. Leipzig 1:68, 1822.

*Puccinia helianthi* Schw. Schrift. Nat. Ges. Leipzig 1:73, 1822.

*Dicaeoma helianthi-mellis* (Schw.) Arth. Result. Sci. Congr. Bot. Vienne 344, 1906; N. Am. Flora 7:427, 1921.

On COMPOSITAE: 0, I, II, III. Autoecious.

*Helianthus annuus* L. Wawawai, Aug. 24, 1894, C. V. Piper 294, Wash. Ured. 2908; Bingen, Sept. 16, 1898, W. N. Suksdorf 548, Wash. Ured. 694; Pullman, Aug. 5, 1915, F. D. Heald and D. C. George, Herb. W.S.C. 172, Wash. Ured. 2731.

**108. *Puccinia hemisphaerica* Ellis & Ev.**

N. Am. Fungi 3144, 1894.

*Aecidium hemisphaericum* Peck. Bot. Gaz. 3:34, 1878.

*Puccinia minussensis* Thüm. Bull. Soc. Nat. Mosc. 53:214, 1878.

*Dicaeoma hemisphaericum* (Peck) Arth. Result. Sci. Congr. Bot. Vienne 344, 1906; N. Am. Flora 7:438, 1921.

On COMPOSITAE: 0, I, II, III. Autoecious.

*Lactuca pulchella* (Pursh.) DC. Wawawai, May 12, 1894, C. V. Piper 261, Arth. Herb., Ellis & Ev. Fungi Columb. 1381b, Wash. Ured. 2893; Locke, July 19, 1917, W. E. Flowers 6008, Wash. Ured. 2507; Guler, June 29, 1919, F. D. Heald, Herb. W.S.C. 646, Wash. Ured. 1301.

**109. *Puccinia heterisiae* Jackson**

Bull. Torrey Club 47:471, 1920.

*Puccinia aspera* Diet. & Holw., Bull. Torrey Club 29:230, 1902. Not *P. aspera* Bon, 1869.

*Micropuccinia heterisiae* (Jackson) Arth. & Jackson, Bull. Torrey Club 48:41, 1921; N. Am. Flora 7:537, 1922.

## ON SAXIFRAGACEAE: 0, III.

*Saxifraga mertensiana* Bong. Mt. Adams, Aug. 7, 1897, W. N. Suksdorf 537 (type); also Aug. 14, 1897, Barth. N. Am. Ured. 619, Arth. Herb., Wash. Ured. 684.

110. *Puccinia heucherae* (Schw.) Diet.

Ber. d. Deutsch. Bot. Ges. 9:42, 1891.

*Uredo heucherae* Schw. Schrift. Nat. Ges. Leipzig 1:71, 1822.

*Puccinia saxifragae* Schlecht. Fl. Berol. 2:134, 1824.

*Puccinia tiarella* B. & C. Grevillea 3:53, 1874.

*Puccinia spreia* Pk. Ann. Rep. N. Y. State Mus. 29:67, 1878.

*Puccinia congregata* E. & H. Bull. Calif. Acad. Sci. 1:26, 1884.

*Micropuccinia heucherae* (Schw.) Arth. & Jackson, Bull. Torrey Club 48:41, 1921; N. Am. Flora 7:535, 1922.

## ON SAXIFRAGACEAE: 0, III.

*Heuchera cylindrica* Dougl. Falcon Valley, July 26, 1883, W. N. Suksdorf 38, Ellis N. Am. Fungi 1463, Arth. Herb., Wash. Ured. 507; Bingen, May 29, 1884, W. N. Suksdorf; Port Orchard, July 15, 1895, C. V. Piper 433, Arth. Herb., Wash. Ured. 2913.

*Heuchera glabella* T. & G. Chiquash Mt., Aug. 28, 1895, W. N. Suksdorf 461, Wash. Ured. 674; Pullman, June 25, 1913, J. G. Hall, Arth. Herb.; Spokane, July 4, 1914, W. E. Flowers 6031, Wash. Ured. 2529.

*Heuchera micrantha* Dougl. Cape Horn, June 7, 1904, C. V. Piper, Herb. W.S.C.

*Leptaxis menziesii* (Pursh.) Raf. Lake Cushman, Aug., 1895, C. V. Piper 467, Herb. W.S.C., Wash. Ured. 1308; Seattle, July 12, 1898, C. V. Piper 436, Herb. W.S.C.; also by E. W. D. Holway, July 9, 1894; Medina, Nov. 15, 1919, G. Howard, Wash. Ured. 328.

*Mitella breweri* Gray. Chiquash Mts., Aug. 28, 1895, W. N. Suksdorf 456, Wash. Ured. 669; Skamania Co., Aug. 28, 1895, W. N. Suksdorf 535, Arth. Herb.; Mt. Rainier, Aug. 24, 1901, E. W. D. Holway, N. Am. Ured. 1149, Fungi Columb. 4965, Arth. Herb.

*Mitella caulescens* Nutt. Silverton, July 8, 1920, C. R. Stillinger 719, Wash. Ured. 825.

*Mitella diversifolia* Greene. Bingen, May 21, 1906, W. N. Suksdorf 1054, Wash. Ured. 754.

*Mitella pentandra* Hook. Mt. Adams, Sept. 21, 1899, W. N. Suksdorf 550, Wash. Ured. 696; Paradise Valley, Mt. Rainier, E. W. D. Holway, Aug. 23, 1901, Barth. N. Am. Ured. 1554, Arth. Herb.

*Saxifraga arguta* D. Don (*Micranthes arguta* (D. Don) Small). Mt. Adams, Aug. 7, 1885, W. N. Suksdorf 210, Wash. Ured. 557; also Sept. 21, 1899, W. N. Suksdorf 543, Wash. Ured. 689; Silverton, July 7, 1920, C. R. Stillinger, Arth. Herb.

*Saxifraga bracteosa* Suks. Bingen, Aug. 31, 1893, W. N. Suksdorf 260, Wash. Ured. 582.

*Saxifraga fragosa* Suks. Klickitat Co., Dec. 31, 1893, W. N. Suksdorf, Barth. N. Am. Ured. 454, Arth. Herb.

*Saxifraga mertensiana* Bong. Paradise Valley, Aug. 23, 1901, E. W. D. Holway 991, Barth. N. Am. Ured. 1451, Arth. Herb.

*Saxifraga occidentalis* Wats. Spangle, May 12, 1916, W. N. Suksdorf 1065, Wash. Ured. 763.

*Tellima grandiflora* (Pursh) Dougl. Seattle, Aug. 8, 1894, C. V. Piper 63, Arth. Herb.; White Salmon River, June 17, 1896, W. N. Suksdorf 534, Wash. Ured. 682; Bainbridge Is., July 24, 1909, E. Bartholomew, Barth. Fungi Columb. 3171, Arth. Herb.; Port Orchard, Aug. 1, 1912, E. Bartholomew, Barth. N. Am. Ured. 849, Arth. Herb.; Seattle, June, 1919, Wash. Ured. 134; Friday Harbor, July, 1919, G. Howard, Wash. Ured. 266; Snoqualmie Falls, Dec. 10, 1921, Wash. Ured. 275; Ft. Lawton, May 26, 1922, D. Mullen, Wash. Ured. 958.

*Tiarella trifoliata* L. Seattle, Aug., 1892, C. V. Piper 40, Arth. Herb.; Peter's Prairie, Sept. 16, 1902, W. N. Suksdorf 790; Duckabush River, Aug. 9, 1912, E. Bartholomew, Barth. Fungi Columb. 4462, Arth. Herb.

*Tiarella unifoliata* Hook. Chenowith, July 7, 1894, W. N. Suksdorf 387, Wash. Ured. 637; Peter's Prairie, Sept. 16, 1902, W. N. Suksdorf 789, Wash. Ured. 723, Barth. N. Am. Ured. 745; Locke, Sept. 11, 1916, W. E. Flowers 6177, Wash. Ured. 2572.

### 111. *Puccinia hieraciata* (Schw.) Jackson

Brooklyn Bot. Gard. Mem. 1:251, 1918.

*Caeoma* (*Aecidium*) *hieraciatum* Schw. Trans. Am. Phil. Soc. II. 4:292, 1832.

*Puccinia patruelis* Arth. Mycol. 1:245, 1909.

*Dicaeoma hieraciatum* (Schw.) Arth. & Kern, N. Am. Flora 7:366, 1920.

On COMPOSITAE: 0, I. Heteroecious. (II, III on Cyperaceae).

*Crepis intermedia* Gray. Waitsburg, May 4, 1900, R. M. Horner 1436, Arth. Herb.

### 112. *Puccinia hieracii* (Schum.) Mart.

Fl. Mosq. 226, 1812.

*Uredo hieracii* Schum. Enum. Pl. Saell. 2:232, 1803.

*Puccinia rugosa* Billings, in S. Wats. Bot. King's Expl. 414, 1871.

*Puccinia troximontis* Peck, Bot. Gaz. 6:227, 1881.

*Puccinia taraxaci* Plowr., Brit. Ured. 186, 1889.

*Puccinia sejuncta* Sydow, Ann. Myc. 1:326, 1903.

*Bullaria hieracii* (Schum.) Arth. Result. Sci. Congr. Bot. Vienne 346, 1906; N. Am. Flora 7:513, 1922.

## On COMPOSITAE: 0, II, III. Autoecious.

*Agoseris aurantiaca* (Hook.) Greene. Wenatchee, July, 1897, A. D. Elmer, Arth. Herb.

*Agoseris elata* (Nutt.) Greene. Pullman, June 23, 1892, W. R. Hull 173, Arth. Herb., Wash. Ured. 1312.

*Agoseris glauca* (Nutt.) Greene. Spangle, July 3, 1884, W. N. Suksdorf 157, Wash. Ured. 528.

*Agoseris gracilentia* (Gray) Greene. Mt. Adams, June 26, 1883, W. N. Suksdorf 54, Ellis N. Am. Fungi 1452, Wash. Ured. 510.

*Agoseris grandiflora* (Nutt.) Greene. Pullman, July 28, 1899, R. M. Horner 125, Arth. Herb.; Waitsburg, May 23, 1900, R. M. Horner 1455, Arth. Herb.

*Agoseris heterophylla* (Nutt.) Greene. Waitsburg, May 7, 1900, R. M. Horner 1438, Arth. Herb.

*Agoseris* sp. Mt. Adams, July 14, 1900, W. N. Suksdorf 600, Wash. Ured. 713.

*Cichorium intybus* L. Puyallup, Aug. 23, 1909, Barth. Fungi Columb. 3167, Arth. Herb.

*Crepis acuminata* Nutt. Bingen, May 27, 1884, W. N. Suksdorf 175, Wash. Ured. 542, Barth. N. Am. Ured. 540; Almota, June 30, 1894, C. V. Piper 246, Wash. Ured. 2899, Arth. Herb.

*Crepis runcinata* (James) T. & G. Yakima, Sept. 27, 1894, C. V. Piper 307, Wash. Ured. 2910.

*Hieracium albiflorum* Hook. Falcon Valley, June 23, 1893, W. N. Suksdorf 251, Arth. Herb., Barth. N. Am. Ured. 468; Trout Lake, July 17, 1894, W. N. Suksdorf 405, Wash. Ured. 656.

*Hieracium canadense* Michx. Spangle, Aug. 10, 1889, W. N. Suksdorf 1068, Wash. Ured. 766; Pullman, Aug. 5, 1893, C. V. Piper 473, Arth. Herb.; Falcon Valley, Aug. 6, 1893, W. N. Suksdorf 250, Barth. N. Am. Ured. 242, Arth. Herb., Wash. Ured. 575.

*Hieracium columbianum* Rydb. Newport, Sept., 1915, J. R. Weir 31, Arth. Herb.; Locke, Aug. 15, 1917, W. E. Flowers 6018, Wash. Ured. 2517.

*Hieracium gracile* Hook. Mt. Adams, July 14, 1900, W. N. Suksdorf 601, Wash. Ured. 714.

*Hieracium scouleri* Hook. Bingen, June 16, 1883, W. N. Suksdorf 67, Wash. Ured. 518; Pullman, June 27, 1898, C. V. Piper 381, Arth. Herb., Wash. Ured. 2925; Almota, June 30, 1898, C. V. Piper 245, Arth. Herb.; Spokane, Aug. 15, 1920, W. E. Flowers 6384, Wash. Ured. 1245.

This species, as interpreted by Arthur and Mains in N. Am.

Flora, is composed of several well marked races, which are morphologically indistinguishable. Some of these are familiar to many observers as independent species. For instance, those forms occurring on *Agoseris* have gone under the name *P. rugosa* Billings or *P. troximontis* Peck, those on *Taraxacum* as *P. taraxaci* Plowr. (cf. 165).

### 113. *Puccinia holboellii* (Hornem.) Rostr.

Meddelser om Groenland 3:534, 1888.

*Aecidium holboellii* Hornem. Fl. Dan. 37:11, 1840.

*Puccinia barbarae* Cooks, Grevillea 8:34, 1879.

*Micropuccinia holboellii* (Hornem.) Arth. & Jackson, Bull. Torrey Club 48: 41, 1921; N. Am. Flora 7:532, 1922.

On CRUCIFERAE: 0, III.

*A cruciferous plant.* Fort Coville, 1861, Dr. Lyall 61, Kew Herb. Reported by Dr. Lyall as *P. barbarae* Cooke in the "Oregon Boundary Commission."

*Arabis furcata* Wats. Mt. Adams, July 29, 1885, W. N. Suksdorf 212, Wash. Ured. 559; Spokane, July 21, 1896, C. V. Piper 440, Wash. Ured. 2919.

*Arabis holboellii* Hornem. Spokane, May 5, 1914, W. E. Flowers 6292, Wash. Ured. 2583.

*Arabis lyallii* S. Wats. Mt. Adams, Aug. 7, 1885, W. N. Suksdorf 211, Arth. Herb., Wash. Ured. 588; Mt. Rainier, Aug., 1895, C. V. Piper 482, Arth. Herb.

### 114. *Puccinia holcina* Erikss.

Ann. Sci. Nat. VIII. 9:274, 1899.

*Dicoma holcinum* (Erikss.) Arth. & From, N. Am. Flora 7:311, 1920.

On POACEAE: II, III (0, I unknown).

*Holcus lanatus* L. Bainbridge Island, July 23, 1909, E. Bartholomew, Barth. Fungi Columb. 3172, Arth. Herb.; Rolling Bay, July 28, 1909, E. Bartholomew, N. Am. Ured. 41, Arth. Herb.; Alki Pt., Aug. 16, 1909, E. Bartholomew, Barth. Fungi Columb. 3173, Arth. Herb.; Bremerton, July 20, 1912, E. Bartholomew, N. Am. Ured. 851, Arth. Herb.; Puyallup, Oct. 3, 1918, A. Frank, Wash. Ured. 419; Startup, May 12, 1919, A. Frank, Wash. Ured. 441; Olympia, May 27, 1919, C. R. Stillinger, Arth. Herb.; Winslow, Oct. 13, 1919, H. H. Hotson, Wash. Ured. 327; Hoquiam, July 2, 1920, C. R. Stillinger & G. B. Posey 797, Arth. Herb., Wash. Ured. 1095; Langley, Aug., 1921, J. M. Grant, Wash. Ured. 301; Ft. Lawton, May 27, 1922, D. Mullen, Wash. Ured. 961; Coupeville, June 20, 1922, Wash. Ured. 981; Seattle, Sept., 1922, Wash. Ured. 1190.

This is a very common rust on velvet grass in western Washing-

ton. It should not be confused with *P. rhamni*, which has uredinia and telia on the same host. The teliospores can be readily distinguished by the apical projections of *P. rhamni*. These species are more difficult to distinguish if only urediniospores are present. Those of *P. holcina* are somewhat larger, measuring 19-24 by 23-27  $\mu$  and globoid, while those of *P. rhamni* are globoid or broadly ellipsoid measuring 16-20 by 18-24  $\mu$ .

The mycelium of this rust remains viable in the host all winter, producing fresh crops of urediniospores from time to time. In early spring these spores infect the leaves of the young *Holcus* plants. It thus does not require the aecial stage to perpetuate itself.

### 115. *Puccinia intermixta* Peck

Bot. Gaz. 4:218, 1879.

*Aecidium intermixtum* Peck, Bot. Gaz. 4:231, 1879.

*Dicaeoma intermixtum* (Peck) Kuntze, Rev. Gen. 3:469, 1898.

*Allodus intermixta* (Peck) Arth. Result. Sci. Congr. Bot. Vienne 345: 1906; N. Am. Flora 7:474, 1921.

On COMPOSITAE: 0, I, III. Autoecious.

*Iva axillaris* Pursh. Pasco, July 11, 1897, C. V. Piper 411, Wash. Ured. 2921; Spokane, Aug. 10, 1913, W. E. Flowers 6117, Wash. Ured. 2551; Wenatchee, Aug. 16, 1916, J. R. Weir, Barth. N. Am. Ured. 2104, Arth. Herb.; Ephrata, June 27, 1921, C. S. Parker, Herb. W.S.C. 849, Wash. Ured. 2790.

### 116. *Puccinia interveniens* (Peck) Bethel

Univ. Calif. Publ. Bot. 7:119, 1919.

*Roestelia interveniens* Peck, Bull. Torrey Club 10:74, 1883.

*Aecidium roestelioides* Ellis & Ev. Jour. Myc. 1:93, 1885.

*Aecidium malvastri* P. Henn. Hedwigia 36:216, 1897.

*Aecidium interveniens* Farl. Bibl. Index N. Am. Fungi, 1:58, 1905.

*Dicaeoma interveniens* (Peck) Arth. & Fromme, N. Am. Flora 7:299, 1920.

On MALVACEAE: 0, I (III on Poaceae, *opsis* form).

*Sidalcea oregona* Gray. Spangle, June 26, 1884, W. N. Suksdorf 144, Wash. Ured. 525.

*Sidalcea* sp. Spokane, June 2, 1913, W. E. Flowers 6127, Wash. Ured. 2557.

*Sphaeralcea rivularis* (Dougl.) Torr. Spokane, June 26, 1884, W. N. Suksdorf, Arth. Herb.

"*Puccinia interveniens* is an heteroecious *opsis*-*Puccinia* (*allodus*), the only one known on grasses. The aecia occur on several genera of the Malvaceae in the West. *Puccinia burnettii*, which is placed as a synonym of *P. interveniens* in the N. Am. Flora (l. c.), has uredinia and telia but the aecial host is unknown." (From a letter from Prof. Jackson).

**117. *Puccinia iridis* (DC.) Rabenhorst**

Krypt. Fl. Deutschl. 1:23, 1844.

*Uredo iridis* DC. Poir. in Lam. Encycl. 8:224, 1808.*Dicaeoma iridis* (DC.) Kuntze, Rev. Gen. 3:469, 1898; N. Am. Flora 7:379, 1920.

On IRIDACEAE: II, III (0, I unknown).

*Iris missouriensis* Nutt. Falcon Valley, Sept. 21, 1894, W. N. Suksdorf 400, Arth. Herb., Barth. N. Am. Ured. 43, Wash. Ured. 654; Yakima, July 10, 1915, Arth. Herb., Wash. Ured. 76.

**118. *Puccinia jonesii* Peck**

Bot. Gaz. 6:226, 1881.

*Puccinia cymopteri* Diet. & Holway, Bot. Gaz. 18:255, 1893.*Puccinia traversiana* Sydow, Monog. Ured. 1:889, 1904.*Allodus jonesii* (Peck) Arth. Result. Sci. Congr. Bot. Vienne 345, 1906; N. Am. Flora 7:463, 1921.

On UMBELLIFERAE: 0, I, III.

*Cogswellia gormani* (How.) Jones. Spokane, July 6, 1920, W. E. Flowers 6410, Wash. Ured. 1254.

*Cogswellia macrocarpa* (Nutt.) Jones. Pullman, Apr., 1895, C. V. Piper 476, Arth. Herb.

*Cogswellia suksdorfii* (Wats.) Jones. West Klickitat Co., July 15, 1883, W. N. Suksdorf 77, Wash. Ured. 521; Husum, May, 1884, W. N. Suksdorf 173, Wash. Ured. 541; Klickitat River, Klickitat Co., Aug. 12, 1919, Geo. Zundel, Arth. Herb.

*Cogswellia triternata* (Pursh) Jones. Bingen, June 24, 1886, W. N. Suksdorf 315, Wash. Ured. 591.

*Cogswellia* sp. Pullman, Apr. 23, 1915, F. D. Heald & D. C. George, Herb. W.S.C. 12, Wash. Ured. 2703; Connell, July, 1916, B. F. Dana, Herb. W.S.C., Wash. Ured. 1296.

*Leptotaenia multifida* Nutt. Pullman, June 4, 1894, C. V. Piper 264, Arth. Herb., Wash. Ured. 1191; Walla Walla, June 29, 1899, C. L. Shear, Arth. Herb.; Waitsburg, June 2, 1900, R. M. Horner, Arth. Herb.; Spokane, July 10, 1914, W. E. Flowers 6014, Wash. Ured. 2513.

*Leptotaenia purpurea* (Wats.) C. & R. Bingen, May 23, 1884, W. N. Suksdorf 169, Wash. Ured. 537; West Klickitat Co., May, 1884, W. N. Suksdorf 242, Arth. Herb.

**119. *Puccinia koeleriae* Arth.**

Mycologia 1:247, 1909.

*Dicaeoma koeleriae* (Arth.) Arth. & From., N. Am. Flora 7:325, 1920.

On BERBERIDACEAE: 0, I. Heteroecious.

*Berberis aquifolium* Pursh. Sumner, June 14, 1916, A. Frank, Wash. Ured. 445; Oak Harbor, Aug. 27, 1919, Wash. Ured. 315;



Seattle, Sept., 1920, Wash. Ured. 186; Langley, May 17, 1921, A. Reuter, Wash. Ured. 1192; Lacey, July 24, 1922, Wash. Ured. 997; Olympia, July 24, 1922, Wash. Ured. 996; Winslow, July 30, 1922, Wash. Ured. 1207; Port Orchard, June 9, 1923, A. J. Sultzer, Wash. Ured. 1812.

*Berberis repens* Lindl. Spokane, July 4, 1914, W. E. Flowers 6004, Wash. Ured. 2503.

On POACEAE: II, III.

*Koeleria cristata* (L.) Pers. Spokane, Sept. 26, 1912, W. E. Flowers 6120, Wash. Ured. 2553.

**120. *Puccinia lapsanae* Fuckel**

Symb. Myc. 53, 1869.

*Aecidium lapsanae* Schultz Prodr. Fl. Stargard 454, 1806.

*Dicaeoma lapsanae* (Schultz) Kuntze, Rev. Gen. 3:469, 1898; N. Am. Flora 7:435, 1921.

On COMPOSITAE: 0, I, II, III. Autoecious.

*Lapsana communis* L. Yarrow, Oct., 1920, Grace Howard, Wash. Ured. 191; Tacoma, March 29, 1924, T. C. Frye, Wash. Ured. 1330.

**121. *Puccinia leveillei* Mont.**

in C. Gay Fl. Chil. 8:41, 1852.

*Puccinia geranii* Lev. Ann. Sci. Nat. III. 5:270, 1846. Not *P. geranii* Corda, 1840.

*Micropuccinia leveillei* (Mont.) Arth. & Jackson, Bull. Torrey Club 48:41, 1921; N. Am. Flora 7:540, 1922.

On GERANIACEAE: 0, III.

*Geranium incisum* Nutt. Waitsburg, May, 1900, R. M. Horner, Ellis & Ev. Fungi Columb. 1572, Arth. Herb.

*Geranium viscosissimum* Fisch. & May. Pullman, June 24, 1914, B. F. Dana, Herb. W.S.C. 302, Wash. Ured. 2746.

**122. *Puccinia ligustici* Ellis & Ev.**

Bull. Torrey Club 22:363, 1895.

*Puccinia luteobasis* Ellis & Ev. Bull. Torrey Club 24:457, 1897.

*Micropuccinia ligustici* (Ellis & Ev.) Arth. & Jackson, Bull. Torrey Club 48:42, 1921; N. Am. Flora 7:552, 1922.

On UMBELLIFERAE: 0, III.

*Ligusticum apiifolium* (Nutt.) Gray. Mt. Rainier, Aug. 23, 1901, E. W. D. Holway, Barth. N. Am. Ured. 1456, Arth. Herb.

*Ligusticum grayi* C. & R. Mt. Rainier, Aug., 1895, C. V. Piper 449, Wash. Ured. 2918.

*Ligusticum* sp. Mt. Adams, July 14, 1900, W. N. Suksdorf 599, Arth. Herb.

"This species is correlated with *Dicaeoma bistortae* (*Puccinia*

*bistortae*) the telial characters of the two species being quite similar, as well as the habitats, and the family to which the hosts of the short-cycled form belong being the same as that of the known aecial host of the heteroecious species." N. Am. Flora 7:522, 1922.

### 123. *Puccinia linkii* Klotzsch

Linnaea 8:490, 1833.

*Puccinia pringlei* Peck, Bot. Gaz. 6:275, 1881.

*Micropuccinia linkii* (Klotzsch) Arth. & Jackson; Bull. Torrey Club 48:42, 1921; N. Am. Flora 7:569, 1922.

On CAPRIFOLIACEAE: 0, III.

*Viburnum pauciflorum* Pyl. Lake Chelan, Aug. 26, 1916, J. R. Weir 14438, Arth. Herb.; Locke, Aug. 25, 1918, W. E. Flowers 6145, Wash. Ured. 1239.

### 124. *Puccinia macclatchieana* Diet. & Holw.

Erythraea 2:127, 1894.

*Dicaeoma macclatchieanum* (Diet. & Holw.) Arth. N. Am. Flora 7:342, 1920.

On CYPERACEAE: II, III. Heteroecious. (0, I unknown).

*Scirpus microcarpus* Presl. Seattle, Aug., 1893, C. V. Piper, Arth. Herb.; Falcon Valley, Oct. 1, 1902, W. N. Suksdorf 1091, Wash. Ured. 788; Bothell, Nov. 12, 1921, Wash. Ured. 253; Medina, Nov. 12, 1921, Wash. Ured. 252; Kirkland, Nov. 12, 1921, Wash. Ured. 251; Houghton, Nov. 2, 1921, Wash. Ured. 232; Battleground, Aug. 7, 1922, Wash. Ured. 1020; Bush Prairie, Aug. 7, 1922, Wash. Ured. 1019; Willapa, Aug. 23, 1922, Wash. Ured. 1023; Ilwaco, Aug. 24, 1922, Wash. Ured. 1025; Nesel River, Aug. 24, 1922, Wash. Ured. 1030; Bay Center, Aug. 24, 1922, Wash. Ured. 1026; Raymond, Aug. 30, 1922, Wash. Ured. 1033; Chehalis, Sept. 2, 1922, Wash. Ured. 1037; Ocosta, Sept. 7, 1922, Wash. Ured. 1049; Markham, Sept. 7, 1922, Wash. Ured. 1048; Westport, Sept. 7, 1922, Wash. Ured. 1045; Aberdeen, Sept. 7, 1922, Wash. Ured. 1047; Hoquiam, Sept. 7, 1922, Wash. Ured. 1046; Dabob, Sept. 8, 1922, Wash. Ured. 1050; Montesano, Sept. 8, 1922, Wash. Ured. 1051; Shine, Sept. 11, 1922, Wash. Ured. 1052; Winslow, Oct. 20, 1923, Wash. Ured. 1219.

It will be observed that in this paper the specific name is always begun with a small letter irrespective of its derivation. It would seem wise in the case of the rust under consideration to modify the specific name slightly to conform to this general rule. Dietel and Holway writes the name thus, *Puccinia McClatchieana*.

**125. *Puccinia majanthae* (Schum.) Arth. & Holw.**

Bull. Lab. Nat. Hist. Univ. Iowa 5:188, 1901.

*Puccinia sessilis* Schneider, Schröter Abh. Schles. Ges. 49:19, 1870.

*Dicaeoma majanthae* (Schum.) Arth. Proc. Ind. Acad. Sci. 1903; 149, 1904;  
N. Am. Flora 7:298, 1920.

On LILIACEAE: 0, I. Heteroecious. (II, III on Poaceae).

*Vagnera sessilifolia* (Baker) Greene. Spokane, July 12, 1910,  
W. E. Flowers 6419, Wash. Ured. 1153; Chelan, Aug., 1916, J. R.  
Weir 11230, Arth. Herb.

**126. *Puccinia malvacearum* Bertero**

in C. Gay, Fl. Chil. 8:43, 1852.

*Micropuccinia malvacearum* (Bertero) Arth. & Jackson, Bull. Torrey Club  
48:41, 1921; N. Am. Flora 7:542, 1922.

On MALVACEAE: 0, III.

*Althaea rosea* (L.) Cav. Bingen, July 1, 1900, W. N. Suksdorf  
610, Wash. Ured. 719; Bremerton, E. Bartholomew, Barth. Fungi Col-  
umb. 4463, Arth. Herb.; Spokane, June 10, 1914, W. E. Flowers 6290,  
Wash. Ured. 2581; Yakima, July 4, 1914, Wash. Ured. 350; Clarkston,  
July 5, 1915, B. F. Dana, Herb. W.S.C. 82, Wash. Ured. 2713; Puy-  
allup, Oct. 25, 1916, A. Frank, Wash. Ured. 433; Winslow, Dec. 10,  
1918, Wash. Ured. 197; Pullman, July 1, 1920, G. L. Zundel, Wash.  
Ured. 161; Sumner, Oct. 5, 1920, Wash. Ured. 189; Walla Walla,  
June 23, 1921, B. F. Dana, Herb. W.S.C. 805, Wash. Ured. 2786;  
Langley, Aug., 1921, J. M. Grant, Wash. Ured. 299; Seattle, Nov. 8,  
1921, Wash. Ured. 225; Georgetown, Nov. 10, 1921, Wash. Ured. 229;  
Lacey, July 24, 1922, Wash. Ured. 998; Tenino, Aug. 18, 1922, Wash.  
Ured. 1193; Woodland, Aug. 16, 1922, Wash. Ured. 1021.

*Malva rotundifolia* L. Bingen, Nov. 10, 1903, W. N. Suksdorf  
967, Wash. Ured. 733; Olympia, Sept. 12, 1912, E. Bartholomew,  
Barth. N. Am. Ured. 1162, Arth. Herb.; Wawawai, June 7, 1915,  
D. C. George, Herb. W.S.C. 23, Wash. Ured. 2704; Yakima, June 18,  
1915, F. D. Heald, Herb. W.S.C. 43, Wash. Ured. 2709; Clarkston,  
Aug. 14, 1915, F. D. Heald & D. C. George, Herb. W.S.C. 193, Wash.  
Ured. 2732; Pullman, June 20, 1916, B. F. Dana, Herb. W.S.C. 280,  
Wash. Ured. 2745; Walla Walla, May 30, 1919, C. R. Stillinger,  
Arth. Herb.; Spokane, Oct. 4, 1920, C. R. Stillinger 741, Wash. Ured.  
844; Winslow, Nov. 4, 1921, Wash. Ured. 312; Seattle, Nov. 9, 1921,  
Wash. Ured. 228; Georgetown, Nov. 10, 1921, Wash. Ured. 230;  
Bothell, Nov. 12, 1921, Wash. Ured. 253; Medina, Nov. 12, 1921,  
Wash. Ured. 262; Kirkland, Nov. 12, 1921, Wash. Ured. 257; Ray-  
mond, Aug., 1922, Wash. Ured. 1214; Ilwaco, Aug., 1922, Wash.  
Ured. 1215; Bay Center, Aug., 1922, Wash. Ured. 1216; Oysterville,

Aug., 1922, Wash. Ured. 1217; Aberdeen, Aug., 1922, Wash. Ured. 1218.

*Malva sylvestris* L. Seattle, Nov. 8, 1921, Wash. Ured. 226; Winslow, Oct. 2, 1922, Wash. Ured. 1068.

*Malva* sp. Bingen, June 10, 1903, W. N. Suksdorf 966, Wash. Ured. 732.

### 127. *Puccinia melanconioides* Ellis & Hark.

Bull. Calif. Acad. 1:27, 1884.

*Allodus melanconioides* (Ellis & Hark.) Arth. Result. Sci. Congr. Bot. Vienne 345, 1906; N. Am. Flora 7:464, 1921.

On PRIMULACEAE: 0, I, III. Autoecious.

*Dodecatheon puberulum* (Nutt.) Piper. Locke, June 13, 1916, W. E. Flowers 6350, Wash. Ured. 2600.

This species resembles *P. ortonii*, a Eu-type.

### 128. *Puccinia menthae* Pers.

Sny. Fungi 227, 1801.

*Aecidium menthae* Sow. Engl. Fungi pl. 398, f. 3, 1803.

*Puccinia clinopodii* DC. Fl. Fr. 6:67, 1815.

*Puccinia menthae americana* Burrill, Bull. Ill. Lab. Nat. Hist. 2:191, 1885.

*Dicoma menthae* (Pers.) S. F. Gray, Nat. Arr. Brit. Pl. 1:542, 1821; N. Am. Flora 7:405, 1921.

On LABIATAE: 0, I, II, III. Autoecious.

*Mentha canadensis* L. Falcon Valley, July 31, 1885, W. N. Suksdorf 204, Wash. Ured. 554; Bingen, July 22, 1893, W. N. Suksdorf 254, Barth. N. Am. Ured. 246, Arth. Herb., Wash. Ured. 578; Pullman, Aug. 16, 1894, C. V. Piper 506, Arth. Herb.; Lake Park, July 27, 195, C. V. Piper 485, Arth. Herb., Wash. Ured. 2914; Seattle, Oct. 1, 1900, C. V. Piper 759, Arth. Herb.; also Dec. 10, 1909, T. C. Frye, Arth. Herb., Wash. Ured. 69; Rolling Bay, July 30, 1912, E. Bartholomew, Fungi Columb. 4464, Herb. W.S.C.: Spokane, Sept. 10, 1914, W. E. Flowers 6016, Wash. Ured. 2515; Kennewick, Aug. 18, 1915, F. D. Heald, Herb. W.S.C. 208, Wash. Ured. 2734; Locke, Sept. 14, 1916, W. E. Flowers 6017, Wash. Ured. 2516; Puyallup, Oct. 20, A. Frank, Wash. Ured. 447; Deep Creek, Sept. 24, 1920, G. L. Zundel, Wash. Ured. 2770.

*Mentha spicata* L. Bingen, May 18, 1904, W. N. Suksdorf 975, Wash. Ured. 740; Bremerton, Aug. 2, 1912, E. Bartholomew, Barth. Fungi Columb. 4465, Arth. Herb.; Seattle, June. 1914, Wash. Ured. 73.

*Mentha* sp. Chelan, Aug., 1916, J. R. Weir 11219, Arth. Herb.; Mineral, July 26, 1921, J. S. Boyce 886, Arth. Herb.

**129. *Puccinia mesomajalis* Berk. & Curt.**

Ann. Rep. N. Y. State Mus. 25:111, 1873.

*Micropuccinia mesomajalis* (Berk. & Curt.) Arth. & Jackson, Bull. Torrey Club 48:41, 1921; N. Am. Flora 7:524, 1922.

On LILIACEAE: 0, III.

*Clintonia uniflora* Kunth. Bingen, June 5, 1883, W. N. Suksdorf 57, Wash. Ured. 511; Skamania Co., July 22, 1894, W. N. Suksdorf, N. Am. Ured. 48; Mt. Adams, Sept. 5, 1900, W. N. Suksdorf 604, Wash. Ured. 77; Mt. Rainier, Aug. 26, 1901, E. W. D. Holway, Herb. W.S.C.; Mt. Baldy, July, 1904, G. H. Martin, Wash. Ured. 348; east side of Mt. Adams, Aug. 25, 1907, W. N. Suksdorf 1059, Wash. Ured. 758; Locke, July 2, 1915, W. E. Flowers 6036, Wash. Ured. 2533; Silverton, July 8, 1920, C. R. Stillinger 720, Wash. Ured. 852; Sol Duc Hot Springs, July 14, 1920, J. S. Boyce 627, Wash. Ured. 2854.

**130. *Puccinia micromeriae* Dudley & Thompson**

Jour. Myc. 10:54, 1904.

*Dicaeoma micromeriae* (Dudley & Thompson) Arth. N. Am. Flora 7:406, 1921.

On LABIATAE: 0, I, II, III. Autoecious.

*Micromeria chamissonis* (Benth.) Greene. Husum, June 26, 1893, W. N. Suksdorf 241, Wash. Ured. 567; Bingen, June 21, 1894, W. N. Suksdorf 412, Wash. Ured. 662; Port Orchard, July 23, 1895, C. V. Piper 424, Herb. W.S.C.; Locke, Sept. 20, 1917, W. E. Flowers 6181, Wash. Ured. 2573.

**131. *Puccinia millefolii* Fuckel**

Jahrb. Nass. Ver. Nat. 23-24:55, 1870.

*Puccinia conferta* Diet. & Holw., Erythraea 7:250, 1893.

*Puccinia recondita* Diet. & Holw., Erythraea 2:128, 1894. Not *P. recondita* Roberge, 1857.

*Puccinia artemisiicola* Sydow Monog. Ured. 1:14, 1902.

*Micropuccinia millefolii* (Fuckel) Arth. & Jackson, Bull. Torrey Club 48:41, 1921; N. Am. Flora 7:582, 1922.

On COMPOSITAE: 0, III.

*Achillea millefolium* L. Hartford, July 9, 1920, G. B. Posey & C. R. Stillinger 735, Wash. Ured. 838; Aberdeen, Oct., 1922, E. Bethel, Wash. Ured. 1076. Mr. E. Bethel reports collecting this rust during October, 1922, on the above host at Montesano, Oakville, Elmer, Wishkali, Ocosta, Cosmopolis and Hoquiam.

*Artemisia suksdorfii* Piper. Pullman, July 28, 1894, C. V. Piper 270, Arth. Herb.; Bainbridge Is., Aug. 17, 1909, E. Bartholomew, Barth. Fungi Columb. 3169, Arth. Herb.

*Ramona incana* (Benth.) Dougl. Spokane, June 11, 1919, W. E. Flowers 6287, Wash. Ured. 1242.

**132. *Puccinia monoica* (Pk.) Arth.**

Mycologia 4:61, 1912.

*Aecidium monoicum* Peck, Bot. Gaz. 4:230, 1879.

*Dicaeoma monoicum* (Peck) Arth. & From., N. Am. Flora 7:312, 1920.

On CRUCIFERAE: 0, I. Heteroecious. (II, III on Poaceae).

*Arabis canescens* (Nutt.) T. & G. (*A. puberula* Nutt.). Klickitat River, June 12, 1885, W. N. Suksdorf 357, Wash. Ured. 619.

*Arabis cusickii* S. Wats. Ellensburg, May 20, 1897, C. V. Piper 414, Arth. Herb.

*Arabis holboellii* Hornem. Spokane, Apr. 10, 1919, W. E. Flowers 6013, Wash. Ured. 2512; Locke, May 5, 1916, W. E. Flowers 6113, Wash. Ured. 1236.

*Arabis whitedii* Piper. Cashmere, Apr., 1910, V. Pease, Arth. Herb.

*Parrya menziesii* Gr. Columbus, Apr. 13, 1886, W. N. Suksdorf 334, Wash. Ured. 609.

**133. *Puccinia mutabilis* Ellis & Gall.**

Jour. Myc. 5:67, 1889.

*Dicaeoma mutabile* (Ellis & Gall.) Kuntze, Rev. Gen. 3:469, 1898; N. Am. Flora 7:373, 1920.

On LILIACEAE: 0, I, II, III. Autoecious.

*Allium geyeri* S. Wats. Ellensburg, June 1, 1897, C. V. Piper 439, Arth. Herb.

*Allium textile* Nelson & Macbr. Spokane, 1918, J. R. Weir 12981, Arth. Herb.

**134. *Puccinia nuda* Ellis & Ev.**

Jour. Myc. 3:57, 1887; N. Am. Flora 7:598, 1922.

*Puccinia hemisporiae* Ellis & Tracy, Jour. Myc. 7:43, 1891.

*Puccinia lagophyllae* Diet. & Holw.; Erythraea 1:250, 1893.

*Puccinia madiarum* Sydow, Monog. Ured. 1:121, 1902.

On COMPOSITAE: II, III (0, I unknown).

*Lagophylla ramossissima* Nutt. Bingen, July 1, 1892, W. N. Suksdorf 1069, Wash. Ured. 767; Klickitat Co., Aug. 26, 1893, W. N. Suksdorf, issued as Barth. N. Am. Ured. 453, Arth. Herb.; Pullman, July 25, 1898, C. V. Piper 593, Arth. Herb.

*Madia sativa* Moline. Bingen, June 28, 1900, W. N. Suksdorf 603, Barth. N. Am. Ured. 1060, Wash. Ured. 716; Falcon Valley, July 10, 1900, W. N. Suksdorf 595, Wash. Ured. 708.

*Madia* sp. Falcon Valley, July 30, 1885, W. N. Suksdorf 200, Arth. Herb., Wash. Ured. 550, distributed as on "*Arnica foliosa* Nutt."

The above disposition of *P. hemisporiae* E. & T., *P. madiarum* Sydow

and *P. lagophyllae* Diet. & Holw. as synonyms of *P. nuda* E. & E. is in accordance with Jackson's arrangement as given in *Mycologia* 14:115, 1922, and also as in the *N. Am. Flora*, 7:598, 1922.

**135. *Puccinia obscura* Schroet.**

Pass. *Nuovo Giorn. Bot. Ital.* 9:256, 1877.

*Aecidium bellidis* Thüm. *Fungi Austr.* 635, hyponym, 1873.

*Dicaeoma obscurum* (Schroet.) Kuntze, *Rev. Gen.* 3:469, 1898; *N. Am. Flora* 7:370, 1920.

*Puccinia bellidis* Lagerh. *Bol. Soc. Broter.* 8:134, 1890.

*Puccinia luzulae-maximae* Dietel, *Ann. Myc.* 17:57, 1919.

On JUNCACEAE: II, III. Heteroecious. (0, I, on Compositae but not found in America).

*Juncoides campestre* (L.) Kuntze. Bingen, May 21, 1894, W. N. Suksdorf 409, Wash. Ured. 659.

*Juncoides parviflorum* (Ehrh.) Cov. Eatonville, Aug. 28, 1901, E. W. D. Holway, Barth. *N. Am. Ured.* 558 and 1462, *Arth. Herb.*; Bremerton, July 31, 1912, E. Bartholomew, *Arth. Herb.*; Bothell, Nov. 12, 1921, Wash. Ured. 263; Willapa, Aug. 23, 1922, Wash. Ured. 1024; Bay Center, Aug. 24, 1922, Wash. Ured. 1027; Seattle, June 2, 1924, M. Myers, Wash. Ured. 1337.

**136. *Puccinia ortonii* Jackson**

Brooklyn Bot. Gard. Mem. 1:259, 1918.

*Dicaeoma ortonii* (Jackson) Arth., *N. Am. Flora* 7:400, 1920.

On PRIMULACEAE: 0, I, II, III. Autoecious.

*Dodecatheon tetrandrum* Suks. Mt. Adams, Aug. 31, 1886, W. N. Suksdorf 324, Barth. *N. Am. Ured.* 554 and 1457, *Arth. Herb.*, Wash. Ured. 599 and 600; Chiquash Mt., Aug. 28, 1898, W. N. Suksdorf 324b; Wash. Ured. 1194.

This species resembles *P. melanconioides* which occurs on the same host. It is, however, distinguished by producing uredinia in its life cycle, which the latter does not have. The two species are probably correlated forms.

**137. *Puccinia pallido-maculata* Ellis & Ev.**

Holway *N. Am. Ured.* 1:49, 1906.

*Micropuccinia pallido-maculata* (E. & E.) Arth. & Jackson, *N. Am. Flora* 7:535, 1922.

On SAXIFRAGACEAE: 0, III.

*Saxifraga odontoloma* Piper. (*S. arguta* D. Don.). Mt. Adams, Oct. 1, 1898, W. N. Suksdorf 355, Wash. Ured. 617. Reported by E. W. D. Holway in his *N. Am. Ured.* 1:49, 1906.

**138. *Puccinia complicata*** (Arth. & Orton) comb. nov.

*Puccinia palmeri* Diet. & Holw. *Erythea* 7:98, excl. synonymy, 1899.

*Allodus palmeri* Orton, Mem. N. Y. Bot. Gard. 6:202, 1916. Not *A. palmeri* Arth. 1906.

*Allodus complicata* Arth. & Orton, N. Am. Flora 7:472, 1921.

On SCROPHULARIACEAE: 0, I, III. Autoecious.

*Pentstemon confertus* Dougl. Lake Chelan, Aug. 26, 1916, J. R. Weir 14442, Arth. Herb.

*Pentstemon pinetorum* Piper. Selah, July 7, 1893, C. V. Piper 130, Arth. Herb.

*Pentstemon venustus* Dougl. Dayton, Sept. 4, 1922, E. Bethel, Wash. Ured. 1195.

*Pentstemon* sp. Lake Chelan, Aug. 26, 1916, J. R. Weir 15842, Arth. Herb.; Medalline Falls, Sept. 26, 1915, J. R. Weir 15527, Arth. Herb.

This species should not be confused with *P. pentstemonis* Peck, a short-cycled form occurring on the same host. The presence of aecia readily distinguishes *P. complicata*.

**139. *Puccinia parkerae*** Diet. & Holw.

*Erythea* 3:78, 1895.

*Micropuccinia parkerae* (Diet. & Holw.) Arth. & Jackson, N. Am. Flora 7:539, 1922.

On SAXIFRAGACEAE: 0, III.

*Ribes lacustre* (Pers.) Poir. Seattle, June, 1894, A. M. Parker, Wash. Ured. 63, Holw. N. Am. Ured. 52, Arth. Herb.; Chiquash Mt., July 20, 1894, W. N. Suksdorf 408, Wash. Ured. 658; Winslow, June 25, 1920, Wash. Ured. 351.

This short-cycled rust has teliospores resembling those of *P. grossulariae* which has its aecia on *Ribes*. *P. ribis*, another short-cycled form, has been reported on *Ribes triste*. The latter species, however, has verrucose teliospores, while those of *P. parkerae* are smooth. All three species occur in Washington.

**140. *Puccinia pattersoniana*** Arth.

Bull. Torrey Club 33:29, 1906.

*Dicaeoma pattersonianum* (Arth.) Arth. & From., N. Am. Flora 7:330, 1920.

On LILIACEAE: 0, I. Heteroecious.

*Hookera douglasii* (Wats.) Piper. Pullman, May 22, 1894, C. V. Piper, Arth. Herb.; Spokane, A. A. Heller 2940, Apr. 21, 1896, Arth. Herb.; Locke, May 1, 1918, W. E. Flowers 6179, Wash. Ured. 1101.

On POACEAE: II, III.

*Sitanion jubatum* Smith. Oakesdale June 5, 1919, C. R. Stillinger, Arth. Herb.



This rust is distinguished from other grass rusts by its verrucose teliospores with the markings arranged in longitudinal lines. The pedicels of the teliospores are stained dark blue by iodine, a characteristic seen also in *P. moreniana*, a short-cycled form found in California, and probably related to the rust under consideration. It has recently been definitely shown that the aecial stage of *P. pattersoniana* occurs on species of *Brodiaea* (Hookera) (Mains, E. B. Ind. Acad. Sci. 1921: 133-135, and Garrett, A. O. Mycologia 16:33-35, 1924). This stage usually has been considered the aecial stage of *Uromyces brodiaeae* E. & E.

#### 141. *Puccinia pentstemonis* Peck

Bull. Torrey Club 12:35, 1885.

*Micropuccinia pentstemonis* (Peck) Arth. & Jackson, N. Am. Flora 7:565, 1922.

On SCROPHULARIACEAE: 0, III.

*Pentstemon confertus* Dougl. Pullman, June 28, 1898, C. V. Piper 377, Wash. Ured. 2923.

This species should not be confused with *P. complicata*, an opsis form occurring on the same host (cf. 138).

#### 142. *Puccinia phaceliae* Syd. & Holw.

Sydow Monog. Ured. 1:314, 1902.

*Micropuccinia phaceliae* (Syd. & Holw.) Arth. & Jackson, N. Am. Flora 7:557, 1922.

On HYDROPHYLLACEAE: 0, III.

*Phacelia sericea* (Graham) Gray. Mt. Rainier, Aug. 23, 1901, E. W. D. Holway (type specimen), Arth. Herb., Barth. N. Am. Ured. 1464.

This rust resembles rather closely other micro-forms coming on the Hydrophyllaceae. In *P. hydrophylli* the teliospores are closely and finely verrucose while those of *P. phaceliae* are smooth and those of *P. romanzoffiae*, reported for Oregon, are marked by large sparsely distributed, irregular tubercles.

#### 143. *Puccinia pimpinellae* (Str.) Mart.

Fl. Mosq. ed. 2:226, 1817.

*Uredo pimpinellae* Strauss, Ann. Wett. Ges. 2:102, 1810.

*Puccinia osmorrhizae* Cke. & Peck, Ann. Rep. N. Y. State Mus. 29:73, 1878.

*Puccinia trifoliatae* E. & E., Bull. Torrey Club 22:58, 1895.

*Dicaeoma pimpinellae* (Str.) Kuntze, Rev. Gen. 3:470, 1898; N. Am. Flora 7:396, 1920.

On UMBELLIFERAE: 0, I, II, III. Autoecious.

*Osmorrhiza brevipes* (C. & R.) Suks. Seattle, June, 1892, E. W. D. Holway, Arth. Herb.; also April 8, 1910, T. C. Frye, Wash. Ured.

69; Bingen, June 5, 1894, W. N. Suksdorf 388, Wash. Ured. 638; Falcon Valley, Aug. 4, 1903, W. N. Suksdorf 1092, Wash. Ured. 789; Friday Harbor, June 14, 1909, T. C. Frye, Arth. Herb., Wash. Ured. 359; Winslow, June 5, 1919, Wash. Ured. 352; Marysville, Aug. 21, 1920, Wash. Ured. 175; Glacier, Aug. 27, 1920, F. Renner, Wash. Ured. 295; Langley, May 17, 1921, A. Reuter, Wash. Ured. 193.

*Osmorrhiza divaricata* Nutt. Bainbridge Island, July 28, 1909, E. Bartholomew, Barth. Fungi Columb. 3174, Barth. N. Am. Ured. 357, Arth. Herb.; Spokane, July 14, 1914, W. E. Flowers 6293, Wash. Ured. 2584; Locke, May 15, 1915, W. E. Flowers 6402, Wash. Ured. 1263.

*Osmorrhiza intermedia* (Rydb.) Blank. Spokane, Aug. 20, 1919, R. Posey and C. R. Stillinger, Arth. Herb., Wash. Ured. 801.

*Osmorrhiza nuda* Torr. Renton, Oct. 8, 1894, C. V. Piper 309, Arth. Herb.; Mt. Rainier, Aug. 27, 1901, E. W. D. Holway, Arth. Herb.

#### 144. *Puccinia plumbaria* Peck

Bot. Gaz. 6:228, 1881.

*Aecidium giliae* Peck, Bot. Gaz. 4:230, 1879.

*Puccinia fragilis* Tracey & Gall. Jour. Myc. 4:20, 1888.

*Allodus giliae* (Peck) Orton, Mem. N. Y. Bot. Gard. 6:199, 1916; N. Am. Flora 7:468, 1921.

On POLEMONIACEAE: 0, I, III. Autoecious.

*Gilia capitata* Hook. Bingen, May 14, 1894, W. N. Suksdorf 1073, Wash. Ured. 771.

*Gilia gracilis* (Dougl.) Hook. Husum, Apr. 30, 1884, W. N. Suksdorf 162, Wash. Ured. 532; Falcon Valley, June 24, 1893, W. N. Suksdorf 243, Wash. Ured. 568; Bingen, May 11, 1894, W. N. Suksdorf 984 (I), 985 (III), Wash. Ured. 746; Blue Mts., Columbia Co., Apr. 21, 1900, R. M. Horner 1443, Arth. Herb.; Seattle, 1906, Bonser 48, Arth. Herb.; Spokane, May 4, 1914, W. E. Flowers & J. R. Weir 14470, Arth. Herb.; Silverton, July 8, 1920, C. R. Stillinger 724, Wash. Ured. 829; Pullman, June 27, 1921, C. S. Parker, Herb. W.S.C. 781, Wash. Ured. 2781.

*Gilia humilis* (Greene) Piper. Indian Canyon, May 1, 1913, W. E. Flowers 6253, Wash. Ured. 1317; Locke, May 1, 1918, W. E. Flowers 6377, Wash. Ured. 1253; also Oct. 18, 1921, W. E. Flowers 6409, Wash. Ured. 1252; Kamiak Butte, May 24, 1921, C. S. Parker, Herb. W.S.C. 769, Wash. Ured. 2778.

This rust should not be confused with *P. giliae* Hark, which is also found in Washington and published under the name of *Dicaeoma giliae* in the N. Am. Flora (7:403, 1920). In this same publication *P.*

*plumbaria* Peck, an ophis form, is under the name *Allodus giliae* (7: 468, 1921).

#### 145. *Puccinia polygoni-amphibii* Pers.

Syn. Fung. 227, 1801.

*Aecidium geranii-maculati* Schw. Schr. Nat. Ges. Leipzig 1:67, 1822.

*Dicaeoma polygoni-amphibi* (Pers.) Arth. Proc. Ind. Acad. Sci. 1898: 184, 1899; N. Am. Flora 7:381, 1920.

On POLYGONACEAE: II, III. Heteroecious. (0, I on Geraniaceae).

*Polygonum amphibium* L. Spokane, July 17, 1914, W. E. Flowers 6163, Wash. Ured. 2564.

*Polygonum emersum* (Mich.) Britt. Pullman, July 31, 1894, C. V. Piper 272, Wash. Ured. 1229; Davenport, Aug., 1919, J. R. Weir 11022, Arth. Herb.

*Polygonum hartwrightii* Gray. Bingen, Aug. 20, 1883, W. N. Suksdorf 127, Wash. Ured. 524; Pullman, July 31, 1894, C. V. Piper 272, Arth. Herb.; Bainbridge Is., Aug. 4, 1909, E. Bartholomew, Barth. Fungi Columb. 3176, Arth. Herb.; Seattle, Aug. 26, 1912, Mr. & Mrs. E. Bartholomew, Barth. N. Am. Ured. 961.

*Polygonum* sp. Bingen, Nov. 3, 1896, W. N. Suksdorf 987, Wash. Ured. 747.

#### 146. *Puccinia polygoni-vivipari* H. Dietr.

P. Karst. Not. Sällsk. Faun. Fl. Fenn. 8:221, 1869.

*Puccinia uniformis* Pammel & Hume, Proc. Davenport Acad. 7:250, 1899.

*Dicaeoma polygoni-vivipari* (H. Dietr.) Arth. N. Am. Flora 7:382, 1920.

On UMBELLIFERAE: 0, I, Heteroecious.

*Ligusticum apiifolium* (Nutt.) Gray. Mt. Rainier, Aug. 22, 1901, E. W. D. Holway, Arth. Herb.

On POLYGONACEAE: II, III.

*Polygonum bistortoides* Pursh. Mt. Rainier, Aug., 1895, C. V. Piper 484, Wash. Ured. 2917.

#### 147. *Puccinia porphyrogenita* M. A. Curt.

Thüm. Myc. Univ. 545, 1876.

*Puccinia acuminata* Peck, Ann. Rep. N. Y. State Mus. 23:57, 1873. Not

*P. acuminata* Fuckel, 1870.

*Micropuccinia porphyrogenita* (M. A. Curt.) Arth. & Jackson, Bull. Torrey Club 48:41, 1921; N. Am. Flora 7:553, 1922.

On CORNACEAE: 0, III.

*Cornus canadensis* L. Mt. Rainier, July 28, 1895, C. V. Piper 487, Arth. Herb., Wash. Ured. 2915; also Aug. 20, 1901, E. W. D. Holway, Arth. Herb.; Priest Lake, Sept., 1909, H. Martin, Wash. Ured. 88; Mt. Baker, Aug. 11, 1914, A. S. Hitchcock, Arth. Herb.; Locke, Aug. 10, 1915, W. E. Flowers 6003, Wash. Ured. 2502; Gla-

cier, July, 1918, H. Schmitz, Wash. Ured. 89; Cascade Mts., May 9, 1920, G. Howard, Wash. Ured. 157; Silverton, July 7, 1920, C. R. Stillinger and G. B. Posey 729, Wash. Ured. 834; Glacier, Aug. 27, 1920, F. R. Renner, Wash. Ured. 293.

**148. *Puccinia porri* Wint.**

Rab. Krypt. Fl. 1:200, 1881.

*Uredo porri* Sow. Engl. Fungi pl. 411, 1810.

*Puccinia mixta* Fuckel, Sym. Myc. 58, 1869.

*Dicaeoma porri* (Sow.) Kuntze Rev. Gen. 3:460, 1898; N. Am. Flora 7:374, 1920.

On LILIACEAE: 0, I, II, III. Autoecious.

*Allium schoenoprasum* L. Seattle, June, 1923, C. R. Stillinger 1561, Wash. Ured. 1336.

**149. *Puccinia pulsatillae* Klachbr.**

Math. Term. Közlem. 3:307, 1865.

*Puccinia trautvetteriae* Syd. & Holw., Sydow Monog. Ured. 1:552, 1903.

*Micropuccinia pulsatillae* (Klachbr.) Arth. & Jackson, Bull. Torrey Club 48:41, 1921; N. Am. Flora 7:527, 1922.

On RANUNCULACEAE: 0, III.

*Trautvetteriae grandis* Nutt. Chiquash Mts., Skamania Co., Sept. 2, 1893, W. N. Suskdorf 424; Olympic Mts., Aug., 1895, C. V. Piper 470, Herb. W.S.C.; Paradise Valley, Mt. Rainier (type locality), Aug. 24, 1901, E. W. D. Holway, Herb. W.S.C.

This species has been reported in the United States from only a few locations in the mountain regions of the Pacific Northwest. (See Holway's N. Am. Ured. 1:12, 1902).

**150. *Puccinia punctata* Link**

Ges. Nat. Freunde Berlin Mag. 7:30, 1815.

*Puccinia galii* Schw. Schr. Nat. Ges. Leipzig 1:73, 1822.

*Puccinia galiorum* Link, in Willd. Sp. Pl. 6:76, 1825.

*Dicaeoma punctatum* (Link) Arth. Proc. Ind. Acad. Sci. 1903; 150, 1904; N. Am. Flora 7:417, 1921.

On RUBIACEAE: 0, I, II, III. Autoecious.

*Galium aparine* L. Mt. Rainier, Aug. 27, 1901, E. W. D. Holway. Arth. Herb.; Hoquiam, July 2, 1920, C. R. Stillinger 759, Wash. Ured. 1089.

*Galium asperrium* A. Gray. Pullman, Oct., 1893, C. V. Piper 141, Wash. Ured. 2890.

*Galium triflorum* Michx. Falcon Valley, Sept. 14, 1894, W. N. Suksdorf 383, Wash. Ured. 632; Bingen, Aug. 23, 1897, W. N. Suksdorf 1085, Wash. Ured. 782.

This species should not be confused with *P. ambigua* and *P. rubefaciens* occurring on the same host.

**151. *Puccinia ranunculi* A. Blytt**

Forh. Vid.-Selsk. Christ. 1882:12, 1882.

*Puccinia nuttallii* Ellis & Ev., Bull. Torrey Club 24:283, 1897.

*Micropuccinia ranunculi* (A. Blytt) Arth. & Jackson, Bull. Torrey Club 48:42, 1921; N. Am. Flora 7:530, 1922.

On RANUNCULACEAE: 0, III.

*Ranunculus suksdorfii* Gray. Olympic Mts., Aug., 1895, C. V. Piper 457, Arth. Herb.

**152. *Puccinia rhaetica* Ed. Fisch.**

Bull. Herb. Boiss. 7:420, 1899.

*Micropuccinia rhaetica* (Ed. Fisch.) Arth. & Jackson, N. Am. Flora 7:564, 1922.

On SCROPHULARIACEAE: 0, III.

*Veronica cusickii* Gray. Mt. Rainier, Aug. 25, 1901, E. W. D. Holway; also Sept. 1, 1909, Arth. Herb.

**153. *Puccinia rhamni* (Pers.) Wettst.**

Verh. Zool.-Bot. Ges. Wien 35:545, 1886.

*Aecidium rhamni* Pers. in J. F. Gmel. Syst. Nat. 2:1472, 1791.

*Puccinia coronata* Corda, Ic. Fung. 1:6, 1837.

*Aecidium allenii* G. W. Clinton, Ann. Rep. N. Y. State Mus. 24:93, 1872.

*Puccinia coronifera* Kleb. Zeits. Pflanzenkr. 4:135, 1894.

*Dicaeoma rhamni* (Pers.) Kuntze, Rev. Gen. 3:470, 1898; N. Am. Flora 7:313, 1920.

On ELAEAGNACEAE: 0, I. Heteroecious.

*Lepargyrea canadensis* (L.) Greene. Seattle, 1906, J. C. Hamblen, Arth. Herb.; Friday Harbor, June 20, 1909, T. C. Frye, Wash. Ured. 66; Locke, June 14, 1915, W. E. Flowers 6143, Wash. Ured. 2560; Chesaw, July 4, 1921, C. S. Parker, Herb. W.S.C. 873, Wash. Ured. 2794; Oak Harbor, May 24, 1922, H. N. Putnam, Wash. Ured. 956.

On RHAMNACEAE: 0, I.

*Rhamnus alnifolia* L'Her. Spokane, June 8, 1914, W. E. Flowers 6170, Wash. Ured. 2566; Locke, June 14, 1916, W. E. Flowers 6171, Wash. Ured. 2567.

*Rhamnus purshiana* DC. Northwood Swamp, May 10, 1919, W. E. Muenscher, Arth. Herb.; Hoquiam, July 2, 1920, C. R. Stillinger 758, Wash. Ured. 1197; Silverton, July 5, 1920, C. R. Stillinger 732, Wash. Ured. 836; Charleston, May 22, 1921, G. Howard, Wash. Ured. 1196; Winslow, May 28, 1922, Wash. Ured. 963; Seattle, June 8, 1922, D. Mullen, Wash. Ured. 978.

On POACEAE: II, III.

*Agrostis microphylla* Steud. Bainbridge Is., Aug. 4, 1909, E. Bartholomew 4138, Arth. Herb.

*Avena sativa* L. Oak Harbor, Aug. 1, 1919, Wash. Ured. 1221; Bothell, Nov. 12, 1921, Wash. Ured. 355.

*Calamagrostis aleutica* Trin. Hoquiam, Sept., 1922, E. Bethel.

*Calamagrostis canadensis* (Michx.) Beauv. Hoquiam, July 2, 1920, C. R. Stillinger, Arth. Herb.

*Cinna latifolia* (Trev.) Griseb. Winslow, Oct. 10, 1921, Wash. Ured. 207.

*Holcus lanatus* L. Tacoma, Aug. 18, 1901, E. W. D. Holway 1005, Arth. Herb.; Olympia, June 15, 1919, F. D. Heald, Herb. W.S. C. 609; Winslow, Oct. 13, 1919, H. H. Hotson, Wash. Ured. 326; Hoquiam, July 2, 1920, C. R. Stillinger 711, Wash. Ured. 819; Seattle, Oct., 1920, L. Hartge, Wash. Ured. 190; Snoqualmie Falls, Dec. 10, 1921, Wash. Ured. 270.

*Lolium multiflorum* Lam. Port Orchard, Aug., 1909, E. Bartholomew, Barth. Fungi Columb. 4466, Barth. N. Am. Ured. 1365, Arth. Herb.

*Lolium perenne* L. Rolling Bay, Oct. 9, 1921, Wash. Ured. 201; Winslow, Oct. 9, 1921, Wash. Ured. 202; Seattle, Nov. 15, 1921, Wash. Ured. 288.

*Panicularia pauciflora* (Presl.) Kuntze. Bothell, Aug. 28, 1909, E. Bartholomew 4200, Arth. Herb.; Bremerton, Aug. 1909, E. Bartholomew 4747, Arth. Herb.

This species is commonly known as "oat rust," although it is rarely found on this host in Washington. It is easily recognized by the coronate teliospore.

#### 154. *Puccinia ribis* DC.

Fl. Fr. 2:221, 1805.

*Puccinia pulchella* Peck, Bull. Buffalo Soc. Nat. Sci. 1:66, 1873.

*Micropuccinia ribis* (DC.) Rostr. Plantep. Haandb. 266, 1902; N. Am. Flora 7:538, 1922.

On SAXIFRAGACEAE: 0, III.

*Ribes triste* Pall. Signal Peak Ranger Station, Yakima Co., July 28, 1922, L. N. Gooding and M. Noll, Arth. Herb., Wash. Ured. 999.

This species should not be confused with *P. grossulariae* or *P. parkerae*, also occurring on *Ribes*.

#### 155. *Puccinia rubefaciens* Johans.

Bot. Notiser 1886:174, 1886.

*Micropuccinia rubefaciens* (Johans.) Arth. & Jackson, Bull. Torrey Club 48:41, 1921; N. Am. Flora 7:568, 1922.

On RUBIACEAE: 0, III.

*Galium boreale* L. Pullman, June, 1898, C. V. Piper 379, Arth. Herb., Wash. Ured. 1311; also June 28, 1916, B. F. Dana, Herb. W.

S.C. 314, Wash. Ured. 2750; Spokane, June 11, 1912, W. E. Flowers 6372, Wash. Ured. 1316; also July 4, 1914, W. E. Flowers 6204, Wash. Ured. 2522; Parker Lake, June 8, 1916, W. E. Flowers 6162, Wash. Ured. 1241; Fort George Wright, June 29, 1922, W. E. Flowers 6420, Wash. Ured. 1255.

There are three species of rusts found in Washington on *Galium*; *P. rubefaciens*, a micro-type; *P. ambigua*, an opsis-type, and *P. punctata* a eu-type.

### 156. *Puccinia sauveolens* Rostr.

Forh. Skand. Nat. 11:339, 1874.

*Bullaria sauveolens* (Pers.) Arth. Result. Sci. Congr. Bot. Vienne 346, 1906; N. Am. Flora 7:511, 1922.

On COMPOSITAE: 0, II, III.

*Cirsium arvense* (L.) Scop. Everett, July, 1919, A. Frank, Wash. Ured. 448; also July 4, 1923, Wash. Ured. 1820; Bothell, June 24, 1920, Wash. Ured. 1204; Seattle, July 4, 1920, Wash. Ured. 1205; Marysville, July 15, 1921, Wash. Ured. 1206; Tukwila, June 9, 1923, A. J. Seltzer, Wash. Ured. 1809.

### 157. *Puccinia scandica* Johans.

Bot. Notiser 1886:175, 1886.

*Micropuccinia scandica* (Johans.) Arth. & Jackson, Bull. Torrey Club 48: 41, 1921; N. Am. Flora 7:550, 1922.

On ONAGRACEAE: 0, III.

*Epilobium clavatum* Trel. Mt. Adams, Oct. 1, 1904, W. N. Suksdorf 981, Wash. Ured. 744.

### 158. *Puccinia sherardiana* Körn.

Hedwigia 16:19, 1877.

*Puccinia malvastris* Peck, Bull. Torrey Club 12:35, 1885.

*Puccinia sphaeralceae* Ellis & Ev., Am. Nat. 31:428, 1897.

*Micropuccinia sherardiana* (Körn) Arth. & Jackson, Bull. Torrey Club 48: 41, 1921; N. Am. Flora 7:543, 1922.

On MALVACEAE: 0, III.

*Malvastrum coccineum* (Pursh) Gray. Yakima, June 16, 1915, F. D. Heald, Herb. W.S.C. 42, Wash. Ured. 2708.

*Sidalcea oregana* (Nutt.) Gray. Pullman, July 2, 1898, C. V. Piper 397, Arth. Herb., Wash. Ured. 2926; Spokane, June 10, 1912, W. E. Flowers 6337, Wash. Ured. 2599.

*Sidalcea* sp. Pullman, June 28, 1916, B. F. Dana, Herb. W.S.C. 309, Wash. Ured. 2747.

*Sphaeralcea munroana* (Dougl.) Spach. Yakima, Aug. 3, 1894, C. V. Piper 293, Arth. Herb., Wash. Ured. 2907.

**159. *Puccinia stipae* Arth.**

Bull. Iowa Agr. Coll. Dept. Bot. 1884:160, 1884.

*Dicaeoma stipae* (Arth.) Kuntze, Rev. Gen. 3:470, 1898; N. Am. Flora 7:300, 1920.

On COMPOSITAE: 0, I. Heteroecious.

*Chrysothamus graveolens* (Nutt.) Greene. Locke, July 10, 1917, W. E. Flowers 6026, Wash. Ured. 2524.

On POACEAE: II, III.

*Stipa comata* Trin. & Rupr. Pullman, May 5, 1921, G. L. Zundel, Herb. W.S.C. 784, Wash. Ured. 1279.

**160. *Puccinia subangulata* Holw.**

N. Am. Ured. 1:25, 1905.

*Allodus subangulata* (Holw.) Orton, Mem. N. Y. Bot. Gard. 6:183, 1916; N. Am. Flora 7:456, 1921.

On LILIACEAE: 0, I, III. Autoecious.

*Hookera pulchella* Salisb. Bingen (type locality), May 3, 1899, W. N. Suksdorf, Arth. Herb.; also Apr. 15, 1904, W. N. Suksdorf 972, Wash. Ured. 737.

**161. *Puccinia subcircinata* Ellis & Ev.**

Jour. Myc. 3:56, 1887.

*Allodus subcircinata* (E. & E.) Arth. Result. Sci. Congr. Vienne 345:1906; N. An. Flora 7:477, 1921.

On COMPOSITAE: 0, I, III. Autoecious.

*Senecio atriapiculatus* Rydb. Wawawai, Apr. 26, 1902, C. V. Piper 820, Arth. Herb.

*Senecio hydrophilus* Nutt. Falcon Valley, July 17, 1896, W. N. Suksdorf 530, Arth. Herb.

*Senecio triangularis* Hook. Mt. Adams, Aug., 1885, W. N. Suksdorf, Arth. Herb., Ellis & Ev. N. Am. Fungi 1840.

**162. *Puccinia subnitens* Diet.**

Erythea 3:81, 1895.

*Aecidium sarcobati* Peck, Bot. Gaz. 6:240, 1881.

*Dicaeoma sarcobati* (Peck) Arth. Result. Sci. Congr. Bot. Vienne 344, 1906; N. Am. Flora 7:305, 1920.

On CHENOPODIACEAE: 0, I. Heteroecious.

*Sarcobatus vermiculatus* (Hook.) Torr. Yakima Co., May 28, 1892, L. F. Henderson, Arth. Herb.; Walla Walla, July 25, 1915, W. E. Flowers 6052, Wash. Ured. 2538.

*Spinacia oleracea* Mill. Walla Walla, May 20, 1922, C. L. Robinson, Wash. Ured. 976; also F. D. Heald, Herb. W.S.C. 1015, Wash. Ured. 2810.



## On POACEAE: II, III.

*Distichlis spicata* (L.) Greene. Yakima, July 10, 1915, Arth. Herb., Wash. Ured. 110; Touchet, July 15, 1920, F. George, Wash. Ured. 120; Walla Walla, May 20, 1922, F. D. Heald, Herb. W.S.C. 1017, Wash. Ured. 2811.

This species is morphologically indistinguishable from *Uromyces peckianus* Farl. except that it has two-celled teliospores. The latter, however, is found almost exclusively in salt marshes around Puget Sound and along the coast, while *P. subnitens* is found mostly in the interior.

**163. *Puccinia suksdorfii* Ellis & Ev.**

Jour. Myc. 7:130, 1892.

*Micropuccinia suksdorfii* (Ellis & Ev.) Arth. & Jackson, Bull. Torrey Club 48:41, 1921; N. Am. Flora 7:585, 1922.

## On COMPOSITAE: 0, III.

*Agoseris glauca* (Nutt.) Greene. Spangle (type locality), May 24, 1901, C. V. Piper 756, Arth. Herb.

**164. *Puccinia symphoricarpi* Hark.**

Bull. Calif. Acad. 1:35, 1884.

*Micropuccinia symphoricarpi* (Hark.) Arth. & Jackson, N. Am. Flora 7:570, 1922.

## On CAPRIFOLIACEAE: 0, III.

*Symphoricarpos albus* (L.) Blake. Klickitat Co., Sept., 1884, W. Suksdorf 170, Barth. N. Am. Ured. 574, Wash. Ured. 538; Spokane, July 4, 1914, W. E. Flowers 6010, Wash. Ured. 2509; Locke, June 12, 1915, W. E. Flowers 6160, Wash. Ured. 2562; Seattle, June 14, 1920, G. Howard, Wash. Ured. 160; Sol Duc Hot Springs, July 14, 1920, J. S. Boyce, Wash. Ured. 2861.

*Symphoricarpos* sp. Chiquash Mts., Aug. 19, 1892, W. N. Suksdorf 1070, Wash. Ured. 768.

This micro-form should not be confused with *P. abundans*, a heteroecious eu-type having pycnia and aecia on the same host.

**165. *Puccinia taraxaci* (Reb.) Plowr.**

Brit. Ured. & Ustil. 186, 1889.

*Puccinia phaseoli* var. *taraxaci* Reb. Prodr. Fl. Noem. 356, 1804.

*Bullaria hieracii* (Schum.) Arth. Result. Sci. Congr. Bot. Vienne 346, 1906; N. Am. Flora 7:513, 1922.

## On COMPOSITAE: 0, II, III.

*Taraxacum taraxacum* (L.) Karst. Bingen, July 27, 1893, W. N. Suksdorf 245, Wash. Ured. 570; Sumner, Sept., 1898, C. V. Piper, Arth. Herb.; Poulsbo, Aug. 9, 1909, E. Bartholomew, Barth. Fungi

Columb. 3178, Arth. Herb.; Wenatchee, July 15, 1912, E. Bartholomew, Barth. N. Am. Ured. 868; Spokane, Sept. 2, 1914, W. E. Flowers 6039, Wash. Ured. 2536; Sunnyside, Aug. 21, 1915, F. D. Heald, Herb. W.S.C. 227, Wash. Ured. 2738; Seattle, Sept. 15, 1917, Wash. Ured. 80; Puyallup, Oct. 5, 1917, A. Frank, Wash. Ured. 453; Yarrow, Feb. 29, 1920, G. Howard, Wash. Ured. 156; Hartford, July 9, 1920, C. R. Stillinger 743, Wash. Ured. 846; Kirkland, July 10, 1920, C. R. Stillinger 703, Wash. Ured. 811; Glacier, Aug. 27, 1920, F. R. Renner, Wash. Ured. 294; Pullman, Sept. 20, 1920, F. D. Heald, Herb. W.S.C. 744, Wash. Ured. 2769; Port Townsend, June 22, 1922, Wash. Ured. 983; Nisqually Flats, July 25, 1922, Wash. Ured. 1198.

This species is morphologically indistinguishable from *P. hieracii* but when transferred from *Taraxacum* to the hosts of the latter they fail to produce infection. In the N. Am. Flora these two species are treated as synonyms.

**166. *Puccinia treleasiana* Paz.**

Rab.-Wint.-Paz. Fungi Eur. 3821 (Hedwigia 31:317), 1892.

*Micropuccinia treleasiana* (Paz.) Arth. & Jackson, N. Am. Flora 7:529, 1922.

On RANUNCULACEAE: 0, III.

*Caltha biflora* DC. Skagit Pass, Cascade Mts., Aug., 1892, E. R. Lake and W. R. Hull, Arth. Herb.

**167. *Puccinia triticina* Erikss.**

Ann. Sci. Nat. VIII, 9:270, 1899.

*Dicaeoma clematidis* (DC.) Arth. Result. Sci. Congr. Bot. Vienne 344, 1906; N. Am. Flora 7:333, 1920.

On POACEAE: II, III. Heteroecious. (0, I on Ranunculaceae).

*Triticum vulgare* L. Manette, Aug. 17, 1912, E. Bartholomew, Barth. N. Am. Ured. 1178, Arth. Herb.; Yakima, July 7, 1915, F. D. Heald, Herb. W.S.C. 136, Wash. Ured. 2722; Pullman, July 23, 1915, C. Sax, Herb. W.S.C. 161, Wash. Ured. 2727; Winslow, July 4, 1918, Wash. Ured. 353; Puyallup, July 10, 1918, A. Frank, Wash. Ured. 429; Lind, July 1, 1919, Wash. Ured. 136; Waitsburg, July, 1919, Wash. Ured. 148; Dayton, July, 1919, Wash. Ured. 145; Walla Walla, July, 1919, Wash. Ured. 149; St. John, Aug., 1919, Wash. Ured. 319; Washtucna, Aug., 1919, Wash. Ured. 318; Coupeville, Aug. 2, 1919, Wash. Ured. 314; Garfield, Aug., 1919, Wash. Ured. 320; Oakesdale, Aug., 1919, Wash. Ured. 317; Oak Harbor, Aug. 1, 1919, Wash. Ured. 354; Everett, Aug. 28, 1919, A. Frank, Wash. Ured. 442; Uniontown, Sept. 7, 1919, B. F. Dana, Herb. W.S.C.

681, Wash. Ured. 276; Seattle, Sept. 10, 1919, Wash. Ured. 322; Langley, June, 1922, A. Reuter, Wash. Ured. 988.

This common leaf rust of wheat is morphologically indistinguishable from *P. clematidis* where it is placed in the N. Am. Flora 7:333, 1920. It seems best for the purposes of this article to list the collections on wheat separately as above.

**168. *Puccinia troglodytes* Lindr.**

Medd. Stockh. Högsk. Bot. Inst. 4:6, 1901.

*Dicaeoma troglodytes* (Lindr.) Jackson, Proc. Ind. Acad. Sci. 1915:461, 1916; N. Am. Flora 7:418, 1921.

On RUBIACEAE: II, III. Heteroecious. (0, I unknown).

*Galium triflorum* Michx. Seattle, Sept., 1892, C. V. Piper 61, Arth. Herb.

**169. *Puccinia urticae* (Schum.) Lagerh.**

Mitt. Bad. Bot. Ver. 2:72, 1889. (Not *P. urticae* Barclay, 1888).

*Aecidium urticae* Schum. Enum. Pl. Saell. 2:222, 1803.

*Caeoma urticatum* Link, in Willd. Sp. Pl. 6:62, 1825.

*Dicaeoma urticae* (Schum.) Kuntze, Rev. Gen. 3:467, 1898; N. Am. Flora 7:358, 1920.

*Puccinia garrettii* Arth. Bull. Torrey Club 32:41, 1905.

*Puccinia urticata* Kern. Mycol. 9:214, 1917.

On URTICACEAE: 0, I. Heteroecious.

*Urtica lyallii* Wats. Spokane, May 30, 1913, W. E. Flowers 6037, Wash. Ured. 2534; Puyallup, June 3, 1919, A. Frank, Wash. Ured. 421; Ft. Lawton, May, 1922, L. Sundquist, Wash. Ured. 965; Winslow, June 9, 1922, Wash. Ured. 1199.

On CYPERACEAE: II, III.

*Carex amplifolia* Boott. Spokane, June 1, 1892, L. F. Henderson, Arth. Herb.

*Carex cryptocarpa* Mey. Chelan, Aug., 1916, J. R. Weir 11226, Arth. Herb.; Winslow, Oct. 5, 1922, Wash. Ured. 1220.

*Carex kelloggii* Booth. Spokane, Sept. 7, 1912, W. E. Flowers 6125, Wash. Ured. 2556.

*Carex magnifica* Dewey. Bothell, Aug. 28, 1921, E. Bartholomew. Barth. Fungi Columb. 3170, Arth. Herb.

*Carex mertensii* Pres. Silverton, July 8, 1920, C. R. Stillinger 754, Arth. Herb., Wash. Ured. 1084; Barlow Pass, Aug. 6, 1920, F. Renner, Arth. Herb.

*Carex nebraskensis* Dewey. Oakedale, July 20, 1919, Wash. Ured. 139.

*Carex rostrata* Stokes. Falcon Valley, Sept. 2, 1886, W. N. Suks-

dorf 313, Wash. Ured. 589; Bainbridge Is., Aug. 4, 1909, Mrs. C. R. Ingle, Arth. Herb.

*Carex utriculata* Boott. Bainbridge Is., Aug. 4, 1909, Mrs. C. R. Ingle, Arth. Herb.

*Carex* sp. Pullman, Oct. 23, 1916, F. D. Heald and D. C. George, Herb. W.S.C. 449.

This species is similar to *P. grossulariae* Lagerh. except that the aecial host is different.

### 170. *Puccinia veratri* Duby

Bot. Gall. 2:890, 1830.

*Uredo veratri* DC., Poir. in Lam. Encyc. 8:224, 1808.

*Puccinia veratri* Niessi. Verh. Zool.-Bot.-Ges. Wien. 9:177, 1859.

*Puccinia veratri* Clinton, Rep. N. Y. State Mus. 27:103, 1875.

*Dicaeoma veratri* (DC.) Kuntze, Rev. Gen. 3:471, 1898; N. Am. Flora 7:371, 1920.

On ONAGRACEAE: 0, I. Heteroecious.

*Epilobium paniculatum* Nutt. Falcon Valley, June 23, 1893, W. N. Suksdorf, Barth. N. Am. Ured. 436, Arth. Herb.

On LILIACEAE: II, III.

*Veratrum californicum* Durand. Falcon Valley, June 28, 1883, W. N. Suksdorf 72, Barth. N. Am. Ured. 577, Wash. Ured. 519; Port Orchard, June 9, 1923, A. J. Seltzer, Wash. Ured. 1807.

*Veratrum speciosum* Rydb. Seattle, July 4, 1897, C. V. Piper 410, Arth. Herb.

### 171. *Puccinia violae* (Schum.) DC.

Fl. Fr. 6:62, 1815.

*Aecidium violae* Schum. Enum. Pl. Saell. 2:224, 1803.

*Puccinia densa* Diet. & Holw., Hedwigia 36:298, 1897.

*Dicaeoma violae* (Schum.) Kuntze, Rev. Gen. 3:471, 1898; N. Am. Flora 7:392, 1920.

On VIOLACEAE: 0, I, II, III. Autoecious.

*Viola adunca* Smith. Bingen, Apr. 8, 1885, W. N. Suksdorf 180, Wash. Ured. 546; Elma, July 19, 1898, A. A. Heller, Plants of Wash. 4066, Arth. Herb.; Pullman, June 23, 1892, W. R. Hull 176, Herb. W.S.C.; Hillyard, May 10, 1914, W. E. Flowers 6225, Wash. Ured. 2576.

*Viola canadensis* L. Locke, Aug. 14, 1917, W. E. Flowers 6032, Wash. Ured. 2530.

*Viola glabella* Nutt. Falcon Valley, July 31, 1885, W. N. Suksdorf 203, Ellis N. Am. Ured. 672, Arth. Herb., Wash. Ured. 553; Husum, May 13, 1895, W. N. Suksdorf 459, Wash. Ured. 672; Olympic Mts., Aug., 1895, C. V. Piper 458, Herb. W.S.C.; Chiquash

Mts., Skamania Co., Aug. 28, 1895, W. N. Suksdorf 460, Wash. Ured. 673; Bingen, July 19, 1897, W. N. Suksdorf 544, Ellis N. Am. Ured. 1574, Wash. Ured. 690; Mt. Rainier, Aug. 27, 1901, E. W. D. Holway, N. Am. Ured. 1478; Bellingham, June, 1913, J. R. Weir 13. Arth. Herb.; Prindle, May 26, 1924, W. N. Suksdorf 1103, Wash. Ured. 1343.

*Viola howellii* Gray. Puyallup, May 26, 1921, A. Frank, Wash. Ured. 406; Rochester, July 26, 1921, A. Frank, Wash. Ured. 444.

*Viola macloskeyi* Lloyd. Silverton, July 8, 1920, G. B. Posey and C. R. Stillinger 721, Wash. Ured. 826.

*Viola montanensis* Rydb. Montesano, 1898, A. A. Heller 4066, Arth. Herb.

*Viola nephrophylla* Greene. Adams Co., Aug., 1893, C. V. Piper 604, Herb. W.S.C.; Yakima, Sept. 7, 1894, C. V. Piper 608, Arth. Herb.

*Viola nuttallii* Pursh. Falcon Valley, May 19, 1897, W. N. Suksdorf 839, Wash. Ured. 685; Spokane, May 10, 1914, W. E. Flowers 6034, Wash. Ured. 2531.

*Viola palustris* L. Longmire Spring, Mt. Rainier, Aug. 20, 1901, E. W. D. Holway, Arth. Herb.

## 172. *Puccinia wulfeniae* Diet. & Holw.

Erythea 3:79, 1895.

*Puccinia synthyridis* Ell. & Ev. Bull. Torrey Club 27:61, 1900.

*Micropuccinia wulfeniae* (Diet. & Holw.) Arthur & Jackson, N. Am. Flora 7:567, 1922.

On SCROPHULARIACEAE: 0, III.

*Synthyris rubra* (Dougl.) Benth. Pullman, June 28, 1898, C. V. Piper 390, Herb. W.S.C., Wash. Ured. 1307.

*Synthyris rotundifolia* Gray. Vancouver, June 8, 1904, C. V. Piper, Herb. W.S.C.

## 173. *Puccinia xanthii* Schw.

Schr. Nat. Ges. Leipzig 1:73, 1822.

*Micropuccinia xanthii* (Schw.) Arth. & Jackson, Bull. Torrey Club 48:42, 1921; N. Am. Flora 7:571, 1922.

On COMPOSITAE: 0, III.

*Ambrosia trifida* L. Spokane, Sept. 9, 1907, W. E. Flowers 6035, Wash. Ured. 2532.

*Xanthium speciosum* Kear. Clarkston, Aug. 14, 1915, F. D. Heald & D. C. George, Herb. W.S.C. 194, Wash. Ured. 2733.

*Xanthium spinosum* L. Spokane, July 21, 1907, W. E. Flowers 6336, Wash. Ured. 2598.

*Xanthium varians* Greene. Dayton, July 21, 1919, Wash. Ured. 142; Waitsburg, July 22, 1919, Arth. Herb., Wash. Ured. 141; also Aug. 11, 1899, R. M. Horner 1246, Herb. W.S.C.

**174. *Puccinia ziziae* Ellis & Ev.**

Bull. Torrey Club 22:60, 1895.

*Bullaria ziziae* (Ellis & Ev.) Arth. Result. Sci. Congr. Bot. Vienne 346, 1906; N. Am. Flora 7:489, 1922.

On UMBELLIFERAE: 0, II, III.

*Zizia cordata* Koch. Pullman, Sept. 24, 1893, C. V. Piper 164, Arth. Herb., Herb. W.S.C. (type location).

**Uromyces Link**

**175. *Uromyces abbreviatus* Arth.**

Bull. Torrey Club 42:587, 1915.

*Teleutospora abbreviata* (Arth.) Arthur & Bisby, N. Am. Flora 7:517, 1922.

On LEGUMINOSAE: 0, III.

*Psoralea physodes* Dougl. Bremerton, July 22, 1912, E. Bartholomew 4752, Arth. Herb., Barth. N. Am. Ured. 7582, Barth. Fungi Columb. 4884.

This species seems to be closely related to *U. psoraleae* Peck (0, I, III); the telia of the two species being morphologically indistinguishable. Both species are found in Washington.

**176. *Uromyces amoenus* Sydow**

Ann. Myc. 4:28, 1906.

*Teleutospora amoenae* (Sydow) Arth. & Bisby, N. Am. Flora 7:519, 1922.

On COMPOSITAE: 0, III.

*Anaphalis margaritacea occidentalis* Greene. Paradise Valley, Mt. Rainier, Aug. 20, 1901, E. W. D. Holway 1008, N. Am. Ured. 1584; Chiquash Mt., Skamania Co., Sept. 9, 1902, W. N. Suksdorf 788 Arth. Herb., Wash. Ured. 722; Spokane, Oct. 4, 1920, C. R. Stillinger 578, Wash. Ured. 805.

**177. *Uromyces brodiaeae* Ell. & Hark.**

Bull. Calif. Acad. 1:28, 1884.

*Aecidium brodiaeae* Ellis & Hark. Bull. Calif. Acad. 1:28, 1884.

*Uromycopsis brodiaeae* Arth. Result. Sci. Congr. Bot. Vienne 345, 1906.

*Pucciniola brodiaeae* (Ellis & Hark.) Arth. N. Am. Flora 7:441, 1921.

On LILIACEAE: 0, I, III. Autoecious.

*Hookera hyacinthina* (Lindl.) Kuntze. Bingen, Apr. 16, 1900, W. N. Suksdorf 982, Wash. Ured. 745. (This specimen has telia only).

Recently it has been shown that the aecia commonly occurring on *Hookera* and considered part of the life cycle of *U. brodiaeae* is in reality the aecial stage of *P. pattersoniana* (Cf. 140).

**178. *Uromyces caladii* (Schw.) Farl.**

- Ellis, N. Am. Fungi 232, 1879.  
*Aecidium caladii* Schw., Schr. Nat. Ges. Leipzig 1:69, 1822  
*Uromyces peltandrae* Howe, Bull. Torrey Club 5:3, 1874.  
*Uromyces arisaemae* Cooke, Bull. Torrey Club 6:32, 1875.  
*Nigredo caladii* (Schw.) Arth. Result. Sci. Congr. Bot. Vienne 343, 1906;  
 N. Am. Flora 7:236, 1912.

On ARACEAE: 0, I, II, III. Autoecious.

*Arisaema triphyllum* (L.) Schott. Seattle, in the green house of the Univ. of Wash., Apr. 10, 1925, Wash. Ured. 1362.

This host is not a native of the state of Washington but has been introduced from the eastern states and probably the rust with it.

**179. *Uromyces caryophyllinus* (Schränk) Wint.**

- in Rab. Krypt. Fl. 1:149, 1881.  
*Lycoperdon caryophyllum* Schränk, Baier. Fl. 2:688, 1789.  
*Uromyces dianthi* Niessl, Verh. Nat. Ver. Brünn 10:162, 1872.  
*Nigredo caryophyllina* (Schränk) Arth. N. Am. Flora 7:246, 1912.

On CARYOPHYLLACEAE: II, III. (0, I on Euphorbiaceae).

*Dianthus caryophyllus* L. Pullman, Feb., 1919, N. F. Thompson, Wash. Ured. 131, Yakima, April 28, 1921, G. B. Rigg, Wash. Ured. 215; Seattle, Nov. 10, 1921, Wash. Ured. 1098; Bothell, Nov. 12, 1921, Wash. Ured. 254; Spokane, Jun. 17, 1922, W. E. Flowers 6358, Wash. Ured. 1102.

The uredinia and telia of this rust are found on certain cultivated varieties of *Dianthus caryophyllus*, especially in greenhouses, where considerable loss to florists sometimes occurs. It came originally from Europe but introduced into Washington from the eastern states or from California.

**180. *Uromyces dictyosperma* Ellis & Ev.**

- N. Am. Fungi 2882, hyponym, 1893; Ann. Myc. 8:12, 1910; not yet published in N. Am. Flora.

On EUPHORBIACEAE: II, III, Heteroecious. (0, I unknown).

*Euphorbia dictyosperma* F. & M. Bingen, May 20, 1908, W. N. Suksdorf 1061, Wash. Ured. 759.

**181. *Uromyces fabae* (Pers.) DeBary**

- Ann. Sci. Nat. IV, 20:80, 1863.  
*Uredo fabae* Pers. Neues Mag. Bot. 1:93, 1794.  
*Uromyces polymorphus* Peck & Clinton, Ann. Rep. N. Y. State Mus. 31:43, 1879.  
*Nigredo fabae* (Pers.) Arth. N. Am. Flora 7:251, 1912.

On LEGUMINOSAE: 0, I, II, III. Autoecious.

*Lathyrus bijugatus sandbergii* White. Mt. Adams, Skamania Co., Aug. 8, 1886, W. N. Suksdorf 323, Arth. Herb., Wash. Ured. 598; Pullman, June 2, 1894, C. V. Piper 263, Wash. Ured. 2895; also June 18, 1921, C. S. Parker, Herb. W.S.C. 791, Wash. Ured. 2784.

*Lathyrus obovatus* (Torr.) White. Locke, Aug. 14, 1917, W. E. Flowers 6395, Wash. Ured. 1144.

*Lathyrus palustris* L. Skamania Co., Aug. 8, 1886, W. N. Suksdorf, Barth. N. Am. Ured. 684, Arth. Herb.; Winslow, June 10, 1919, Wash. Ured. 1329; Friday Harbor, July, 1919, G. Howard, Wash. Ured. 1328.

*Lathyrus pauciflorus* Fernald. Snake River, Whitman Co., July, 1898, C. V. Piper, Wash. Ured. 2929; Adna, Aug. 3, 1922, Wash. Ured. 1017; Napavine, Aug. 3, 1922, Wash. Ured. 1015; Winlock, Aug. 3, 1922, Wash. Ured. 1014; Chehalis, August 4, 1922, Wash. Ured. 1018; Castle Rock, Aug. 18, 1922, Wash. Ured. 1022.

*Lathyrus polyphyllus* Nutt. Olympia, June 28, 1920, C. R. Stillinger 708, Wash. Ured. 816.

*Lathyrus sulphureus* Brewer. Bainbridge Island, July 27, 1912, E. Bartholomew, Barth. N. Am. Ured. 886, Barth. Fungi Columb. 3194, Arth. Herb.

*Vicia americana* Muhl. Falcon Valley, June 1, 1883, W. N. Suksdorf 58 (Ellis N. Am. Fungi 1431 under *Aecidium album* Clinton), Wash. Ured. 512; Pullman, C. V. Piper 592, Arth. Herb.; Wenatchee, July 15, 1912, E. Bartholomew, Barth. Fungi Columb. 4494, Arth. Herb.; Spokane, Aug. 15, 1919, J. R. Weir 14425, Arth. Herb.; Kirkland, July 10, 1920, G. B. Posey and C. R. Stillinger 706, Wash. Ured. 814; Winslow, July 12, 1920, Wash. Ured. 155; Puyallup, July 17, 1921, A. Frank 129, Wash. Ured. 410.

### 182. *Uromyces fallens* (Desmaz.) Kern

Phytopathology 1:6, 1911.

*Uredo fallens* Desmaz. Pl. Crypt. 1325, 1843.

*Nigredo fallens* (Desmaz.) Arthur, N. Am. Flora 7:254, 1912.

On LEGUMINOSAE: 0, I, II, II. Autoecious.

*Trifolium pratense* L. Yakima, Aug., 1914, Wash. Ured. 90; Wenatchee, July 29, 1915, D. C. George, Herb. W.S.C. 165, Wash. Ured. 2728; Kennewick, Aug. 18, 1915, F. D. Heald, Herb. W.S.C. 209, Wash. Ured. 2735; Pullman, Oct. 26, 1920, F. D. Heald, Herb. W.S.C. 749, Wash. Ured. 2771; Rolling Bay, Oct. 30, 1921, Wash. Ured. 217; Houghton, Nov. 12, 1921, Wash. Ured. 233; Medina, Nov. 12, 1921, Wash. Ured. 234; Bothell, Nov. 12, 1921, Wash. Ured. 258;



Aberdeen, Oct., 1922, E. Bethel, Wash. Ured. 1077; Port Townsend, June 22, 1922, Wash. Ured. 982; Winslow, Oct. 28, 1922, Wash. Ured. 1074.

In a letter from Mr. E. Bethel he reports finding *Uromyces fallens* at Montesano, Oakville, Elma, Washkah, Ocota, Cosmopolis, and Hoquiam during October, 1922.

This is the common rust on red clover. The aecia are rarely seen but probably are not uncommon. It is distinguished from another autoecious form, *U. trifolii* occurring on white clover, by the character of the urediniospore pores which are 3-6, scattered, in an occasional spore, equatorial. In the latter species the urediniospore pores are 3 or 4 equatorial.

### 183. *Uromyces gentianae* Arth.

Bot. Gaz. 16:227, 1891.

*Nigredo gentianae* Arth. N. Am. Flora 7:264, 1912.

On GENTIANACEAE: II, III. (0, I unknown).

*Gentiana acuta* Michx. Mt. Adams, Aug. 1, 1890, W. N. Suksdorf 358, Arth. Herb., Wash. Ured. 620.

### 184. *Uromyces glycyrrhizae* (Rab.) Magn.

Ber. Deuts. Bot. Ges. 8:383, 1890.

*Uredo leguminosarum glycyrrhizae* Rab. Flora 33:626, 1850.

*Caecomurus glycyrrhizae* Kuntze, Rev. Gen. 3:450, 1898.

*Klebahnia glycyrrhizae* (Rab.) Arth. Result. Sci. Congr. Bot. Vienne 345, 1906; N. Am. Flora 7:478, 1921.

On LEGUMINOSAE: 0, II, III. Autoecious.

*Glycyrrhiza lepidota* Nutt. Columbus, June 11, 1886, W. N. Suksdorf 235, Wash. Ured. 562; Bingen, Nov. 14, 1894, W. N. Suksdorf 454, Arth. Herb., Wash. Ured. 667; Wawawai, July 31, 1893, C. V. Piper 118, Wash. Ured. 2884; Latch Creek, July 4, 1914, W. E. Flowers 6047, Wash. Ured. 1099; Washtucna, July, 1919, Wash. Ured. 198; Snake River, Asotin Co., Sept. 26, 1922, C. S. Parker, Herb. W. S.C. 1044, Wash. Ured. 2813.

### 185. *Uromyces hedysari-obscuri* (DC.) Carest. & Picc.

Erb. Critt. Ital. II:447, 1871.

*Uromyces borealis* Peck, Bot. Gaz. 6:276, 1881.

*Uromycopsis hedysari-obscuri* Arth. Result. Sci. Congr. Bot. Vienne 345, 1906.

*Pucciniola hedysari-obscuri* (DC.) Arthur, N. Am. Flora 7:450, 1921.

On LEGUMINOSAE: 0, I, III. Autoecious.

*Hedysarum occidentale* Greene. Olympic Mts., Aug., 1895, C. V. Piper 472, Wash. Ured. 1210; Locke, Sept. 13, 1915, W. E. Flowers 6363, Wash. Ured. 1185.

**186. *Uromyces heterodermus* Sydow**

Ann. Myc. 4:29, 1906.

*Teleutospora heteroderma* (Sydow) Arth. & Bisby, N. Am. Flora 7:516, 1922.

On LILIACEAE: 0, III.

*Erythronium giganteum* Lindl. Lake Sawyer, April 30, 1923, Paul Bargeth, Wash. Ured. 1802; Port Orchard, April 8, 1924, A. N. Carlson, Wash. Ured. 1327.*Erythronium grandiflorum* Pursh. Falcon Valley, May 19, 1884, W. N. Suksdorf 166, Arth. Herb., Wash. Ured. 353; Paradise Valley, Mt. Rainier, Aug. 20, 1901, E. W. D. Holway; Bingen, May 7, 1902, W. N. Suksdorf 1089; Locke, June 1, 1916, W. E. Flowers 6166, Wash. Ured. 1104; Kamiak Butte, May 24, 1921, C. P. Parker, Herb. W.S.C. 770, Wash. Ured. 2779.*Erythronium montanum* Wats. Cascade Mts., Skamania Co., Aug. 26, 1895, W. N. Suksdorf 462, Barth. N. Am. Ured. 789, Arth. Herb., Wash. Ured. 675; Mt. Rainier, Aug., 1895, C. V. Piper, Arth. Herb.*Erythronium parviflorum* (Wats.) Goodding. Locke, June 22, 1917, W. E. Flowers 6049, Wash. Ured. 1105.**187. *Uromyces lili* G. W. Clinton**

Ann. Rep. N. Y. State Mus. 27:103, 1875.

*Uromyces holwayi* Lagerh., Hedwigia 28:108, 1889.*Nigredo lili* (G. W. Clinton) Arth. Result. Sci. Congr. Bot. Vienne 344, 1906; N. Am. Flora 7:242, 1912.

On LILIACEAE: 0, I, II, III. Autoecious.

*Lilium columbianum* Hanson. Skamania Co., Sept. 1, 1898, W. N. Suksdorf 546, Arth. Herb., Wash. Ured. 692; Seattle, June 2, 1892, C. V. Piper 58, Arth. Herb.; Bingen, May 27, 1902, W. N. Suksdorf 798, Arth. Herb.; Spokane, Sept., 1915, J. R. Weir 93, Arth. Herb.; Bellingham, Sept., 1918, D. Griffiths, Arth. Herb.; Port Orchard, June 9, 1923, A. J. Seltzer, Wash. Ured. 1806.**188. *Uromyces intricatus* Cooke**

Grevillea 7:3, 1878.

*Uromyces eriogoni* Ellis & Hark., Bull. Calif. Acad. 1:29, 1884.*Uromyces gnaphalii* Ellis & Ev. Erythea 1:204, 1893.*Nigredo intricata* (Cooke) Arth. N. Am. Flora 7:244, 1912.

On POLYGONACEAE: 0, I, II, III. Autoecious.

*Eriogonum compositum* Dougl. Bingen, June 24, 1886, W. N. Suksdorf 325, Arth. Herb., Wash. Ured. 601; Wawawai, July 31, 1893, C. V. Piper 119, Wash. Ured. 2885; Goldendale, Sept. 1, 1915, E. Bartholomew, Barth. N. Am. Ured. 1696, Arth. Herb.

*Eriogonum effusum* Nutt. Spokane, Sept. 12, 1915, W. E. Flowers 6048, Wash. Ured 1142.

*Eriogonum heracleoides* Nutt. Pullman, July 31, 1894, C. V. Piper 275, Arth. Herb., Wash. Ured. 2906.

*Eriogonum niveum* Dougl. Wawawai, June 16, 1892, E. R. Lake, Arth. Herb.

*Eriogonum umbellatum* Torr. Mt. Adams, June 14, 1890, W. N. Suksdorf 359, Wash. Ured. 621; Spokane, July 14, 1907, W. E. Flowers 6101, Wash. Ured. 1141.

*Eriogonum vimineum* Dougl. Bingen, July 5, 1905, W. N. Suksdorf 993, Wash. Ured. 751.

### 189. *Uromyces jacksonii* Arth. & Fromme

Torreya 15:260, 1915.

On POACEAE: II, III. Heteroecious. (0, I unknown).

*Deschampsia elongata* (Hook.) Munro. Bremerton, July 20, 1912, E. Bartholomew, Barth. Fungi Columb. 4460, N. Am. Ured. 1237, Arth. Herb., Wash. Ured. 1305.

*Hordeum nodosum* L. Port Orchard, Aug. 1, 1912. E. Bartholomew, Barth. Fungi Columb. 4495, Arth. Herb.

### 190. *Uromyces junci* (Desmaz.) L.

Tul. Ann. Sci. Nat. IV-2:146, 1854.

*Puccinia junci* Desmaz Pl. Crypt. 81:1825.

*Nigredo junci* (Desmaz) Arthur, N. Am. Flora 7:238, 1912.

On JUNCACEAE: II, III. Heteroecious. (0, I on Compositae).

*Juncus balticus* Willd. Falcon Valley, W. N. Suksdorf 1086, Sept. 28, 1898, Wash. Ured. 783; Pullman, Nov. 10, 1898, C. V. Piper 597, Wash. Ured. 2931; Ilwaco, Sept., 1922, E. Bethel.

*Juncus suksdorfii* Rydb. Falcon Valley, Sept. 2, 1886, W. N. Suksdorf 314, Wash. Ured. 590.

*Juncus torreyi* Cov. Ilwaco, Sept., 1922, E. Bethel.

*Juncus* sp. Houghton, Nov. 12, 1921, Wash. Ured. 268; Spokane, Aug. 21, 1922, W. E. Flowers 6351, Wash. Ured. 1248.

### 191. *Uromyces junci-effusi* Sydow

Monog. Ured. 2:290, 1910.

*Puccinia junci* Schw. Trañs. Am. Phil. Soc. II-4:295, 1832 (not *P. junci* Desmaz. 1825.)

*Uromyces effusus* Arth. Jour. Myc. 13:193, 1907 (not *U. effusus* De-Toni, 1888).

*Nigredo junci-effusi* (Sydow) Arth., N. Am. Flora 7:239, 1912.

On JUNCACEAE: II, III. (0, I unknown, probably on Aster).

*Juncus ensifolius* Wikstr. Falcon Valley, Sept. 17, 1901, W. N. Suksdorf 653, Barth. N. Am. Ured. 1595, Arth. Herb.; Moclips, Aug.

17, 1914, A. S. Hitchcock, Arth. Herb.; Locke, Sept. 13, 1915, W. F. Flowers 6345, Wash. Ured. 1145; Lake Chelan, Aug. 27, 1916, J. R. Weir 11217, Arth. Herb.

*Juncus nevadensis* Wats. Juanita, May 24, 1924, Wash. Ured. 1335.

*Juncus orthophyllus* Cov. Falcon Valley, Sept. 11, 1883, W. N. Suksdorf 49, N. Am. Ured. 689, Wash. Ured. 508; Mt. Chopaka, Aug., 1897, A. D. Elmer, Arth. Herb.

## 192. *Uromyces lupini* Berk. & Curt.

Proc. Am. Acad. 4:126, 1858.

*Uredo lupini* Berk. & Curt. Proc. Am. Acad. 4:126, 1858.

*Uromyces tomentellus* Cooke, Grevillea 6:138, 1878.

*Uromyces astragali lupini* De-Toni, in Sacc. Syll. Fung. 7:550, 1888.

*Nigredo lupini* (Berk. & Curt.) Arth. Result. Sci. Congr. Bot. Vienne 344, 1906; N. Am. Flora 7:252, 1912.

On LEGUMINOSAE: 0, I, II, III. Autoecious.

*Lupinus polyphyllus* Lindl. Falcon Valley, July 24, 1883, W. N. Suksdorf 29, Wash. Ured. 504; also July 20, 1886, W. N. Suksdorf 331, Arth. Herb., Wash. Ured. 606; Manor, July 14, 1899, C. V. Piper 674, Arth. Herb.

*Lupinus suksdorfii* Robinson. Bingen, Nov. 15, 1923, W. N. Suksdorf 1097, Wash. Ured. 1276.

*Lupinus sulphureus* Dougl. Dayton, Sept. 30, 1919, G. L. Zundel, Wash. Ured. 1139.

*Lupinus* sp. Glendale, October 18, 1918, C. R. Stillinger 617, Wash. Ured. 806; Pullman, September 30, 1920, F. D. Heald, Herb. W.S.C. 736, Wash. Ured. 2767; Langley, Sept., 1921, J. M. Grant, Wash. Ured. 300.

## 193. *Uromyces medicaginis* Pass.

Thüm. Herb. Myc. Oecon. 156, 1874.

*Nigredo medicaginis* (Pass.) Arthur, N. Am. Flora 7:256, 1912.

On LEGUMINOSAE: II, III. Heteroecious.

*Medicago lupulina* L. Medina, Nov. 12, 1921, Wash. Ured. 236.

This heteroecious form has its pycnia and aecia on *Euphorbia* in Europe, but not yet found in America.

## 194. *Uromyces miurae* Sydow

Ann. Myc. 11:94, 1913.

*Pucciniola miurae* (Sydow) Arth., N. Am. Flora 7:442, 1921.

On LILIACEAE: III. (0, I unknown).

*Fritillaria lanceolata* Pursh. Falcon Valley, May 19, 1884, W. N. Suksdorf 172, Arth. Herb., Wash. Ured. 540; Liberty Creek, May 11, 1907, T. A. Bonser 42, Arth. Herb.

**195. *Uromyces nerviphila* (Grog.) Comb. Nov.***Puccinia nerviphila* Grognot, Pl. Crypt. Saône-et-Loire 154, 1863.*Uromyces flectens* Lagerh. Sv. Bot. Tidskr. 3:36, 1909.*Pucciniola nerviphila* (Grognot) Arth. N. Am. Flora 7:448, 1921.

On LEGUMINOSAE: 0, I, III.

*Trifolium repens* L. Bingen, July 27, 1894, W. N. Suksdorf 453, Wash. Ured. 666; Kirkland, July 10, 1920, C. R. Stillinger 707, Wash. Ured. 815; Hoquiam, July 2, 1920, C. R. Stillinger 755, Wash. Ured. 1085.

**196. *Uromyces oblongus* Vize**

Grevillea 5:110, 1877.

*Uromyces minor* Schroet. Krypt. Fl. Schles. 3:310, 1887.*Uromycopsis minor* Arth. Result. Sci. Congr. Bot. Vienne 345, 1906.*Pucciniola oblonga* (Vize) Arth., N. Am. Flora 7:447, 1921.

On LEGUMINOSAE: 0, I, III. Autoecious.

*Trifolium ciliolatum* Benth. Bingen, June 7, 1899, W. N. Suksdorf 989, Wash. Ured. 750.

*Trifolium dubium* Sibth. Bingen, May 6, 1894, W. N. Suksdorf, Wash. Ured. 769; Pleasant Beach, Bainbridge Island, July 27, 1912, E. Bartholomew, Barth. Fungi Columb. 4786, Arth. Herb.; Port Blakely, Bainbridge Island, July 27, 1912, E. Bartholomew, Barth. Fungi Columb. 4496, Arth. Herb.; Spokane, June 2, 1914, W. E. Flowers 6318, Wash. Ured. 1143, also June 25, 1919, W. E. Flowers 6332, Wash. Ured. 1260; Olympia, June 28, 1920, C. R. Stillinger 710, Wash. Ured. 818; Winslow, July 6, 1920, Wash. Ured. 150; Langley, May, 1922, J. M. Grant, Wash. Ured. 302.

*Trifolium procumbens* L. Friday Harbor, July 13, 1919, G. Howard, Wash. Ured. 130.

*Trifolium variegatum* Nutt. Bingen, May 23, 1884, W. N. Suksdorf 167, Arth. Herb., Wash. Ured. 536.

**197. *Uromyces occidentalis* Dietel**

Hedwigia Beibl. 42:98, 1903.

*Uromyces rugosus* Arth. Bot. Gaz. 39:386, 1905.*Nigredo occidentalis* (Diet.) Arth., N. Am. Flora 7:252, 1912.

On LEGUMINOSAE: II, III. (0, I unknown).

*Lupinus lyallii* Gray. Mt. Adam, Aug. 10, 1885, W. N. Suksdorf 189, Arth. Herb., Wash. Ured. 547.

**198. *Uromyces peckianus* Farl.**

Proc. Am. Acad. 18:78, 1883.

*Caenomurus peckianus* Kuntze, Rev. Gen. 3:450, 1898.*Nigredo peckiana* (Farl.) Result. Sci. Congr. Bot. Vienne 344, 1906; N. Am. Flora 7:230, 1912.

On CHENOPODIACEAE: 0, I. Heteroecious.

*Atriplex littoralis* L. Fort Lawton, May 26, 1922, Wash. Ured. 1002.

*Salicornia ambigua* Michx. Friday Harbor, May 22, 1909, T. C. Frye, Arth. Herb.; Ft. Lawton, June 21, 1920, Grace Howard, Wash. Ured. 152; Eagle Harbor, June 9, 1923, Wash. Ured. 1814; Rolling Bay, June 10, 1923, Wash. Ured. 1815.

On POACEAE: II, III.

*Distichlis spicata* (L.) Greene. Port Orchard, Aug. 9, 1912, E. Bartholomew, N. Am. Ured. 796, Arth. Herb.; Winslow, June 10, 1920, Wash. Ured. 151; Ft. Lawton, Nov. 11, 1920, Wash. Ured. 153; Rolling Bay, Oct. 2, 1921, Wash. Ured. 212; Port Townsend, Nov. 10, 1922, E. Bethel, Wash. Ured. 1079.

This species is morphologically indistinguishable from *Puccinia subnitens* except in the character of the teliospore.

### 199. *Uromyces perigynius* Halsted

Jour. Myc. 5:11, 1889.

*Uromyces caricinus* Ellis & Ev. Bull. Torrey Club 22:58, 1895.

*Nigredo perigynia* (Halsted) Arth. Result. Sci. Congr. Bot. Vienne 344, 1906; N. Am. Flora 7:235, 1912.

On CYPERACEAE: II, III. Heteroecious. (0, I on Compositae).

*Carex athrostachya* Olney. Spangle, June, 1884, W. N. Suksdorf 146, Wash. Ured. 527.

### 200. *Uromyces polygoni* (Pers.) Fuckel

Symb. Myc. 64, 1869.

*Puccinia polygoni* Pers. Neues Mag. Bot. 1:119, 1794.

*Nigredo polygoni* (Pers.) Arth. Result. Sci. Congr. Bot. Vienne 344, 1906; N. Am. Flora 7:243, 1912.

On POLYGONACEAE: 0, I, II, III. Autoecious.

*Polygonum aviculare* L. Almota, June 22, 1895, C. V. Piper 477, Arth. Herb., Wash. Ured. 2912; Bingen, Aug. 23, 1898, W. N. Suks-551, Wash. Ured. 697; Wiser Lake, Aug. 14, 1909, T. C. Frye, Arth. Herb.; Bremerton, July 17, 1912, E. Bartholomew, Barth. N. Am. Ured. 1295 and 894, Barth. Fungi Columb. 4499, Arth. Herb.; Pullman, July 20, 1916, B. F. Dana, Herb. W.S.C. 394, Wash. Ured. 2758; Puyallup, Sept. 10, 1917, A. Frank 325, Wash. Ured. 434; Seattle, Sept. 10, 1917, Wash. Ured. 79; Kirkland, Sept. 20, 1920, Wash. Ured. 184; Winslow, Sept. 10, 1920, Wash. Ured. 183; Richland, June 15, 1921, G. L. Zundel, Wash. Ured. 1107; Nisqually River, Thurston Co., July 25, 1922, Wash. Ured. 1285.

**201. *Uromyces porosus* (Peck) Jackson**

Brooklyn Bot. Gard. Mem. 1:281, 1918.

*Aecidium porosum* Peck, Bot. Gaz. 3:34, 1878.

*Uromyces coloradensis* Ellis & Ev., Erythraea 1:204, 1893.

*Uromycopsis porosa* Arth. Result. Sci. Congr. Bot. Vienne 345, 1906.

*Pucciniola porosa* (Peck) Arthur, N. Am. Flora 7:450, 1921.

On LEGUMINOSAE: 0, I, III. Autoecious.

*Vicia americana* Muhl. Falcon Valley, June 1, 1883, W. N. Suksdorf, Arth. Herb.; White Salmon River, June 27, 1883, W. N. Suksdorf 76, Wash. Ured. 520; Mt. Adams, July 14, 1886, W. N. Suksdorf 329, Wash. Ured. 604; Seattle, May, 1892, C. V. Piper, Arth. Herb.; Bingen, May 23, 1901, W. N. Suksdorf 1099, Wash. Ured. 1324; Hillyard, June 10, 1914, W. E. Flowers 6056, Wash. Ured. 1106; Pullman, June 30, 1916, B. F. Dana, Herb. W.S.C. 320, Wash. Ured. 2752; Winslow, June 10, 1919, Wash. Ured. 347; Friday Harbor, July, 1919, Grace Howard, Wash. Ured. 129; Wawawai, May 19, 1922, C. S. Parker, Herb. W.S.C. 1048, Wash. Ured. 2815.

*Vicia americana minor* Hook. (*V. linearis* Gr.). Seattle, June, 1892, C. V. Piper, Arth. Herb.

**202. *Uromyces probus* Arthur**

Bull. Torrey Club 38:376, 1911.

*Nigredo proba* Arthur, N. Am. Flora 7:243, 1912.

On IRIDACEAE: 0, I, II, III. Autoecious.

*Olsynium grandiflorum* (Dougl.) Raf. Bingen, July 10, 1893, W. N. Suksdorf 339, Arth. Herb., Wash. Ured. 611; Kamiak Butte, May 24, 1921, C. S. Parker, Herb. W.S.C. 771, Wash. Ured. 2780; Pullman, July 4, 1922, C. S. Parker, Herb. W.S.C. 1051.

**203. *Uromyces proëmiens* (DC.) Pass.**

Rab. Fungi, Eur. 1795, 1873.

*Uredo proëminens* DC. Fl. Fr. 2:235, 1805.

*Uromyces euphorbiae* Cooke & Peck, Ann. Rep. N. Y. State Mus. 25:90, 1873.

*Uromyces macounianus* Ellis & Ev., Proc. Phila. Acad. 1893:155, 1893.

*Nigredo proëminens* (DC.) Arth. N. Am. Flora 7:259, 1912.

On EUPHORBIACEAE: 0, I, II, III. Autoecious.

*Euphorbia glyptosperma* Engelm. Wawawai, Aug. 4, 1899, R. M. Horner 1261, Herb. W.S.C.; Waitsburg, Aug. 24, 1899, R. M. Horner 1260, Herb. W.S.C.

*Euphorbia serpyllifolia* Pers. Bingen, Sept. 20, 1893, W. N. Suksdorf 253, Arth. Herb., Wash. Ured. 577; Oroville, July 20, 1919, L. Y. Leonard, Wash. Ured. 140.

*Euphorbia* sp. Pullman, July, 1920, G. L. Zundel, Wash. Ured 170.

**204. *Uromyces psoraleae* Peck**

Bot. Gaz. 6:239, 1881.

*Uromycopsis psoraleae* Arth. Result. Sci. Congr. Bot. Vienne 345, 1906.

*Pucciniola psoraleae* (Peck) Arthur, N. Am. Flora 7:446, 1921.

On LEGUMINOSAE: 0, I, III. Autoecious.

*Psoralea lanceolata scabra* (Nutt.) Piper. Spokane, Aug. 7, 1913, W. E. Flowers 6033, Wash. Ured. 1155.

**205. *Uromyces punctatus* Schröt.**

Abh. Schles. Ges. 48:10, 1870.

*Uromyces astragali* Sacc. Mycol. Ven. Specim. 208, hyponym, 1873.

*Nigredo punctata* (Schröt.) Arth., N. Am. Flora 7:253, 1912.

On LEGUMINOSAE: II, III. Heteroecious. (0, I on Euphorbiaceae).

*Astragalus adsurgens* Pall. Ft. George Wright, Aug. 10, 1919, W. E. Flowers 6396, Wash. Ured. 1100.

*Astragalus glareosus* Dougl. Bingen, Aug. 3, 1894, W. N. Suksdorf 401, Wash. Ured. 655.

The pycnia and aecia of this heteroecious form have been reported on Euphorbia in Europe but have not yet been found in America.

**206. *Uromyces scirpi* (Cast.) Burrill**

Bot. Gaz. 9:188, 1884.

*Uredo scirpi* Cast. Cat. Pl. Mars. 214, 1845.

*Uromyces lineolatus* Schröt. Rab. Fungi Eur. 2077, 1876.

*Uromyces maritimus* Plowr. Gard. Chron. III-7:746, 1890.

*Uromyces burrillii* Lagerh. Tromö Mus. Aarsh. 17:41, 1895.

*Nigredo scirpi* (Cast.) Arth. Result. Sci. Congr. Bot. Vienne 344, 1906; N. Am. Flora 7:233, 1912.

On CYPERACEAE: II, III. (0, I on Umbelliferae and Primulaceae).

*Scirpus pacificus* Britton. Langley, Oct., 1922, J. M. Grant, Wash. Ured. 1277.

**207. *Uromyces seditiosus* Kern**

Torrey 11:212, 1911.

*Nigredo seditiosa* (Kern) Arthur, N. Am. Flora 7:225, 1912.

On PLANTAGINACEAE: 0, I. Heteroecious. (II, III on Poaceae).

*Plantago eriopoda* Torr. Spokane, July 15, 1914, W. E. Flowers 6118, Wash. Ured. 1156.

**208. *Uromyces silenes* (Schlecht.) Fückel**

Symb. Myc. 61:1869.

*Uromyces pulchellus* Ellis & Ev. Bull. Torrey Club 22:57, 1895.

*Nigredo silenes* (Schlecht.) Arth. N. Am. Flora 7:247, 1912.

On CARYOPHYLLACEAE: 0, I, II, III. Autoecious.

*Silene douglasii multicaulis* (Nutt.) Robinson. Pullman, June 9, 1897, C. V. Piper 405, Wash. Ured. 2920.



*Silene* sp. Lake Chelan, Aug. 14, 1892, C. V. Piper, Arth. Herb.; Bonapart Lake, July 20, 1921, C. S. Parker, Herb. W.S.C. 948, Wash. Ured. 2804.

### 209. *Uromyces silphii* (Burrill) Arthur

Jour. Myc. 13:202, 1907.

*Aecidium compositarum silphii* Burrill, De-Toni in Sacc. Syll. Fung. 7:798, 1888.

*Aecidium silphii* Sydow, Ured. 1546, 1901.

*Uromyces junci-tenuis* Sydow, Monog. Ured. 2:289, 1910.

*Nigredo silphii* (Burrill) Arthur, N. Am. Flora 7:239, 1912.

On JUNCACEAE: II, III. (0, I on Silphium).

*Juncus dudleyi* Wiegand. Pullman, July 20, 1896, A. D. Elmer, Arth. Herb.

*Juncus longistylis* Torr. Spokane Co., Aug. 10, 1899, W. N. Suksdorf, in U. S. Nat. Herb. Phanerogamic No. 2525.

*Juncus tenuis* Willd. Montesano, July 21, 1898, A. A. & E. G. Heller in N. Y. Bot. Gard. Phanerogamic No. 4074.

### 210. *Uromyces solidaginis* (Sommerf.) Neissl.

Verh. Nat.-Ver. Brünn 10:163, 1872.

*Caeoma solidaginis* Sommerf. Suppl. Fl. Lapp. 234, 1826.

*Teleutospora solidaginis* (Sommerf.) Arth. & Bisby, Bull. Torrey Club 48:39, 1921; N. Am. Flora 7:518, 1922.

On COMPOSITAE: 0, III.

*Solidago serotina* Ait. Pullman, July 31, 1894, C. V. Piper, Arth. Herb., Wash. Ured. 1211.

### 211. *Uromyces suksdorfii* Diet. & Holw.

Erythea 3:77, 1895.

On CARYOPHYLLACEAE: 0, I, II, III. Autoecious.

*Silene oregana* Wats. West Klickitat Co., July 17, 1894, W. N. Suksdorf 385, Wash. Ured. 634; Mt. Adams, Aug. 6, 1903, W. N. Suksdorf 970, Wash. Ured. 735.

*Silene scouleri* Hook. Tieton River, July 18, 1901, C. V. Piper 831, Arth. Herb.

### 212. *Uromyces trifolii* (Hedw. f.) Lev.

Ann. Sci. Nat. III-8:371, 1847.

*Puccinia trifolii* Hedw. f., DC. Fl. Fr. 2:225, 1805.

*Nigredo trifolii* (Hedw. f.) Arth. Result. Sci. Congr. Bot. Vienne 344, 1906; N. Am. Flora 7:255, 1912.

On LEGUMINOSAE: 0, I, II, III. Autoecious.

*Trifolium hybridum* L. Bainbridge Island, Aug. 3, 1909, E. Bartholomew, Barth. Fungi Columb. 3197, Arth. Herb.; Bremerton, Aug. 2, 1912, E. Bartholomew, Barth. N. Am. Ured. 899, Arth. Herb.;

Puyallup, Sept. 16, 1919, A. Frank 296, Wash. Ured. 454; Pullman, Oct. 26, 1920, F. D. Heald, Herb. W.S.C. 760, Wash. Ured. 2774; Seattle, May 27, 1923, Vera Stedman, Wash. Ured. 1804.

*Trifolium macrocephalum* Poir. Bingen, Apr. 19, 1899, W. N. Suksdorf 541, Arth. Herb., Wash. Ured. 687.

*Trifolium repens* L. Bremerton, July 31, 1912, E. Bartholomew, Barth. Fungi Columb. 4500, Arth. Herb.; Prosser, Aug. 20, 1915, F. D. Heald, Herb. W.S.C. 216, Wash. Ured. 2736; Fife, Aug. 17, 1917, A. Frank and F. D. Heald, Wash. Ured. 428; Spokane, Aug. 29, 1920, J. R. Weir 14426, Arth. Herb.; Puyallup, Sept. 16, 1920, A. Frank 149, Wash. Ured. 411; Medina, Nov. 12, 1921, Wash. Ured. 235; Bothell, Nov. 12, 1921, Wash. Ured. 259; Kirkland, Nov. 12, 1921, Wash. Ured. 240; Snoqualmie Falls, Dec. 10, 1921, Wash. Ured. 281; Seattle, May 20, 1922, Wash. Ured. 1213; also May 16, 1923, Vera Stedman, Wash. Ured. 1803.

### 213. *Uromyces unitus* Peck

Bull. Torrey Club 10:74, 1883.

*Caenomurus unitus* Kuntze, Rev. Gen. 3:451, 1898.

*Uromycopsis unita* Arth. Result. Sci. Congr. Bot. Vienne 345, 1906.

*Pucciniola unita* (Peck) Arth., N. Am. Flora 7:445, 1921.

On PORTULACACEAE: 0, I, III. Autoecious.

*Lewisia columbiana* (Howell) Robinson. Collected in Washington Territory by T. S. Brandegee, Arth. Herb. (type).

As far as the writer is aware, this is the only record of this rust being collected in the state of Washington. The data on the collection is very meager, no date or definite locality, merely "Washington Territory." There might, therefore, be some doubt whether this collection was really made in this state.

### 214. *Uromyces zygadeni* Peck

Bot. Gaz. 6:239, 1881.

*Uromyces fraseriae* Arth. & Rick. Jour. Myc. 8:128, 1902.

*Nigredo zygadeni* (Peck) Arth. Result. Sci. Congr. Bot. Vienne 344, 1906; N. Am. Flora 7:240, 1912.

On LILIACEAE: 0, I, II, III. Autoecious.

*Zygadenus venenosus* Wats. Locke, May 5, 1916, W. E. Flowers 6136, Wash. Ured. 1238.

## Uropyxis Magnus

### 215. *Uropyxis sanguinea* (Peck) Arthur

N. Am. Flora 7:155, 1907.

*Uromyces sanguineus* Peck, Bot. Gaz. 4:128, 1879.

*Puccinia mirabilissima* Peck, Bot. Gaz. 6:226, 1881.

*Uropyxis mirabilissima* Magn. Ber. Deuts. Bot. Ges. 10:193, 1892.

*Dicaeoma mirabilissimum* Kuntze, Rev. Gen. 3:469, 1898.

On BERBERIDACEAE: 0, II, III. Autoecious.

*Berberis aquifolium* Pursh. Falcon Valley, June 1, 1883, W. N. Suksdorf 59, Ellis N. Am. Fungi 1451, Arth. Herb., Wash. Ured. 513; Charleston, May, 1890, A. Parker, Wash. Ured. 62; Wawawai, April 27, 1913, J. G. Hall, Arth. Herb.; Colfax, Mar. 24, 1918, F. D. Kern, Arth. Herb.; Port Townsend, Apr. 2, 1921, G. L. Zundel, Wash. Ured. 1222; Winslow, May 24, 1921, Wash. Ured. 790; Seattle, May 19, 1922, Wash. Ured. 952; Langley, May, 1922, A. Reuter, Wash. Ured. 194; Port Orchard, June 5, 1922, Wash. Ured. 989; also June 9, 1923, A. J. Seltzer, Wash. Ured. 1808.

*Berberis nervosa* Pursh. Winslow, Sept. 10, 1920, Wash. Ured. 221; Kirkland, Nov. 12, 1921, Wash. Ured. 244.

*Berberis repens* Lindf. Spokane, May 10, 1909, W. E. Flowers 6109, Wash. Ured. 1111; Pullman, April 18, 1915, F. D. Heald, Herb. W.S.C. 9, Wash. Ured. 2702; Spangle, May 12, 1916, W. N. Suksdorf 1064, Wash. Ured. 762; Locke, June 7, 1916, W. E. Flowers 6375, Wash. Ured. 1112.

*Berberis* sp. Sumner, June 7, 1916, A. Frank, Wash. Ured. 358.

Magnus created the genus *Uropyxis* on account of the following characteristics: 1. Teliospores with more than one germ pore. 2. Epispore with a gelatinous layer.

## UREDINALES IMPERFECTI

The telial stage of a rust is the one on which classification is largely based. If for any reason this stage is not known the rust is regarded as imperfect. For convenience these species which are usually spoken of as form genera are put into a group by themselves, and designated as UREDINALES IMPERFECTI.

### KEY TO THE FORM GENERA

#### A. Spores in chains.

##### B. Peridium absent.

CAEOMA (p. 376).

##### BB. Peridium present.

##### C. Peridium toothed, body cup-shaped.

AECIDIUM (p. 375).

##### CC. Peridium fimbriate, body elongate.

(ROESTELIA)\*.

##### CCC. Peridium irregularly split

PERIDERMIMUM (p. 377).

#### AA. Spores not in chains.

(UREDINALES)\*.

### Aecidium Pers.

#### 216. *Aecidium collinsiae* Ellis & Ev.

Bull. Washb. Lab. Nat. Hist. 1:4, 1884; N. Am. Flora 7:637, 1924.

*Aecidium tonellae* D. & H., Erythea 3:77, 1895.

#### On SCROPHULARIACEAE: 0, I.

*Collinsia parviflora* Dougl. Falcon Valley, June 1, 1883, W. N. Suksdorf 63, Wash. Ured. 516; Cle Elum, June 1, 1892, L. F. Henderson, Arth. Herb.; Bingen, May 11, 1894, W. N. Suksdorf 986.

*Collinsia rattani* Gray. Falcon Valley, Apr. 30, 1884, W. N. Suksdorf 160, Wash. Ured. 550.

*Tonella collinsioides* Nutt. Bingen, Aug. 29, 1894, W. N. Suksdorf 380, Wash. Ured. 629.

This is apparently a heteroecious form with its alternate host unknown. It is found only in the Pacific Northwest.

#### 217. *Aecidium columbiense* Ellis & Ev.

Erythea 1:206, 1893; N. Am. Flora 7:644, 1924.

#### On COMPOSITAE: 0, I.

*Hieracium albiflorum* Hook. Falcon Valley, May 10, 1886, W. N. Suksdorf 244A, Wash. Ured. 569A; White Salmon River, May 12, 1886, W. N. Suksdorf 244B, Wash. Ured. 569B; Locke, May 19, 1915, W. E. Flowers 6312, Wash. Ured. 1244; Langley, May 21, 1921, A. Reuter, Wash. Ured. 971; Joyce, May 10, 1912, S. Biggs, Wash. Ured. 949.

\* Not reported as occurring in the State of Washington.

**218. *Aecidium eurotiae* Ellis & Ev.**

Jour. Myc. 6:119, 1891.

On CHENOPODIACEAE: 0, I.

*Eurotia lanata* (Pursh) Moq. Yakima, April, 1898, C. V. Piper 419, Wash. Ured. 1234.

**219. *Aecidium graebnerianum* Henn.**

Hedwigia 37:273, 1898; N. Am. Flora 7:622, 1924.

*Aecidium alaskanum* Trelease, Harr. Alaska Exp. 5:37, 1904.

On ORCHIDACEAE: 0, I.

*Limnorchis dilatata* (Pursh) Rydb. Chiquash Mt., Skamania Co., Aug. 6, 1899, W. N. Suksdorf 540, Wash. Ured. 686; Silverton, July 7, 1920, C. R. Stillinger 700, Wash. Ured. 809.

*Limnorchis leucostachys* Rydb. Chiquash Mts., Skamania Co., Aug. 12, 1886, W. N. Suksdorf 528.

This is probably a heteroecious form with the alternate host unknown. It is found only along the Pacific coast.

**220. *Aecidium humuli* sp. nov.**

On MORACEAE: 0, I.

*Humulus lupulus* L. (Cultivated Hops). During July, 1915, the writer collected the aecial stage of a rust on this host in the Yakima Valley. This is doubtless some heteroecious form but it is difficult to determine where it belongs.

The aecia contort the stem of the host much like those of *Puccinia clematidis* on Clematis. Within half a mile of where this material was collected there was a heavy infection on *Clematis ligusticifolia* Nutt. The writer is not in a position to make any definite statement regarding this rust, but merely wishes to record the fact of its collection. Arth. Herb.; Wash. Ured. 1361.

***Oaeoma* Link****221. *Oaeoma dubium* Ludwig**

Phytopath. 5:281, 1915; N. Am. Flora 7:648, 1924.

On PINACEAE: 0, I.

*Tsuga heterophylla* Sarg. Bainbridge Is., July 17, 1909, E. Bartholomew, Fungi Columb. 3103, Herb. W.S.C.; Silverton, July 1, 1920, C. R. Stillinger 749, Wash. Ured. 851; Kirkland, July 10, 1920, C. R. Stillinger 680, Wash. Ured. 808.

**Peridermium Lev.****222. Peridermium coloradense (Diet.) Arth. & Kern**

Bull. Torrey Club 33:426, 1906; N. Am. Flora 7:647, 1924.  
*Aecidium coloradense* Diet. in E. & P. Nat. Pl. 1<sup>\*\*\*</sup>:78, 1897.  
*Peridermium boreale* Arth. & Kern, Bull. Torrey Club 33:425, 1906.

On PINACEAE: 0, I.

*Picea canadensis* (Mill) B. S. P. Spokane, Aug. 22, 1921, W. E. Flowers 6388, Wash. Ured. 1115.

*Picea engelmanni* Engelm. Parker Lake, Aug. 25, 1915, W. E. Flowers 6392, Wash. Ured. 1116; Locke, July 20, 1917, W. E. Flowers 6098, Wash. Ured. 2547.

*Picea excelsa* Link. Spokane, Aug. 14, 1912, W. E. Flowers 6389, Wash. Ured. 1117.

*Picea sitchensis* Carr. Ilwaco, July, 1918, Wash. Ured. 84; Pacific Co., Aug. 13, 1919, A. Frank, Wash. Ured. 424.

This rust is probably a heteroecious form, having it aecia on species of *Cerastium* but no cultural work has as yet been reported.

**223. Peridermium ornamentale Arth.**

Bull. Torrey Club 28:665, 1901; N. Am. Flora 7:646, 1924.  
*Peridermium holwayi* Sydow, Ann. Myc. 1:19, 1903.

On PINACEAE: 0, I.

*Abies lasiocarpa* (Hook.) Nutt. Chiquash Mt. (type locality), Skamania Co., Aug. 11, 1886, W. N. Suksdorf 296, Arth. Herb., Wash. Ured. 587; Mt. Adams, Sept. 4, 1900, W. N. Suksdorf 588, Arth. Herb., Wash. Ured. 703; Chelan Lake, Aug. 26, 1916, J. R. Weir.

**224. Peridermium rugosum Jackson**

N. Am. Flora 7:646, 1924.

On PINACEAE: 0, I. Heteroecious.

*Abies amabilis* Forbes. Cascade Mts., Snohomish Co., Aug., 1915, H. Schmitz, Arth. Herb.

*Abies grandis* Lindl. Lake Cushman, Oct., 1915, Rose M. Taylor, Arth. Herb. (type locality).

This species is reported elsewhere only from Oregon.

## LOCATION OF PLACES CITED

The following is a list of the places where collections of rusts have been made and the county (*Italics*) in which each is located. If a more accurate location within the county is desired, it is suggested that the reader consult Bulletin 17, entitled "A Geographic Dictionary of Washington," issued by the Washington Geological Survey at Olympia.

- |  |   |
|--|---|
| Aberdeen, <i>Grays Harbor</i>          | Clark Spring, <i>Pend Oreille</i>         |
| Adna, <i>Lewis</i>                     | Clarkston, <i>Asotin</i>                  |
| Alki Point, <i>King</i> , near Seattle | Clear Lake, <i>Skagit</i>                 |
| Almota, <i>Whitman</i>                 | Cle Elum, <i>Kittitas</i>                 |
| Arlington, <i>Snohomish</i>            | Colfax, <i>Whitman</i>                    |
| Auburn, <i>King</i>                    | Colton, <i>Whitman</i>                    |
|  | Columbus, <i>Klickitat</i>                |
| Bainbridge Island, <i>Kitsap</i>       | Connell, <i>Franklin</i>                  |
| Barlow Pass, <i>Snohomish</i>          | Cook, <i>Skamania</i>                     |
| Battle Ground, <i>Clarke</i>           | Cosmopolis, <i>Grays Harbor</i>           |
| Bay Center, <i>Pacific</i>             | Coulee City, <i>Grant</i>                 |
| Belfair, <i>Mason</i>                  | Coupeville, <i>Island</i>                 |
| Bellevue, <i>King</i>                  | Cove, <i>King</i>                         |
| Bellingham, <i>Whatcom</i>             | Crescent Lake, <i>Clallam</i>             |
| Big Four, <i>Snohomish</i>             | Crocker, <i>Jefferson</i>                 |
| Bingen, <i>Klickitat</i>               |   |
| Birch Bay, <i>Whatcom</i>              | Dabob, <i>Jefferson</i>                   |
| Black Diamond, <i>King</i>             | Danville, <i>Ferry</i>                    |
| Blaine, <i>Whatcom</i>                 | Darrington, <i>Snohomish</i>              |
| Blue Mts., <i>Walla Walla</i>          | Davenport, <i>Lincoln</i>                 |
| Bonapart Lake, <i>Okanogan</i>         | Dayton, <i>Columbia</i>                   |
| Boston Harbor, <i>Thurston</i>         | Deep Creek, <i>Spokane</i>                |
| Bothell, <i>King</i>                   | De Lions, <i>Jefferson</i>                |
| Bow, <i>Skagit</i>                     | Deming, <i>Whatcom</i>                    |
| Bremerton, <i>Kitsap</i>               | Dewatto, <i>Mason</i>                     |
| Burley, <i>Kitsap</i>                  | Discovery Bay, <i>Jefferson</i>           |
| Burlington, <i>Skagit</i>              | Dixie, <i>Walla Walla</i>                 |
| Bush Prairie, <i>Clarke</i>            | Doe Bay, <i>San Juan</i>                  |
|  | Dosewallips River, <i>Jefferson</i>       |
| Cape Horn, <i>Skamania</i>             | Duckabush River, <i>Jefferson</i>         |
| Carson, <i>Skamania</i>                | Dungeness, <i>Clallam</i>                 |
| Cashmere, <i>Chelan</i>                |   |
| Castle Point, on Castle Island,        | Eagle Harbor, Bainbridge Island.          |
| <i>San Juan</i>                        | <i>Kitsap</i>                             |
| Castle Rock, <i>Cowlitz</i>            | East Sound, <i>San Juan</i>               |
| Cedar River, <i>King</i>               | Eatonville, <i>Pierce</i>                 |
| Center, <i>Jefferson</i>               | Edison, <i>Skagit</i>                     |
| Charleston, <i>Kitsap</i>              | Edmonds, <i>Snohomish</i>                 |
| Chehalis, <i>Chelan</i>                | Elbe, <i>Pierce</i>                       |
| Chelan, <i>Chelan</i>                  | Ellensburg, <i>Kittitas</i>               |
| Chelan Lake, <i>Chelan</i>             | Elma, <i>Grays Harbor</i>                 |
| Chenoweth, in the southeastern part    | Elwha, <i>Clallam</i>                     |
| of <i>Skamania</i>                     | Emer, <i>Grays Harbor</i>                 |
| Cheney, <i>Spokane</i>                 | Ephrata, <i>Grant</i>                     |
| Chesaw, <i>Okanogan</i>                | Everett, <i>Snohomish</i>                 |
| Chico, <i>Kitsap</i>                   |   |
| Chimacum, <i>Jefferson</i>             | Fairfax, <i>Pierce</i>                    |
| Chiquash Mts., <i>Skamania</i>         | Falcon Valley, in the northwestern        |
| Chiwaukum, <i>Chelan</i>               | corner of <i>Klickitat</i> at the base of |
| Clallam Bay, <i>Clallam</i>            | Mt. Adams                                 |

Ferncliff, on Rolling Bay, Bain-  
bridge Island, *Kitsap*  
Ferndale, *Whatcom*  
Fife, *Pierce*  
Fir, *Skagit*  
Flattop Island, *San Juan*  
Forks, *Clallam*  
Fort Coville, *Stevens*  
Fort George Wright, *Spokane*  
Fort Lawton, *King*  
Freeman, *Spokane*  
Friday Harbor, *San Juan*

Garfield, *Whitman*  
Georgetown, *King*, part of Seattle,  
Gig Harbor, *Pierce*  
Glacier, *Whatcom*  
Glacier Peak, *Whatcom*  
Glendale, *Island*  
Goat Mt., near Mt. Rainier, in  
East Central *Lewis*  
Goldendale, *Klickitat*  
Granite, *Snohomish*  
Granite Falls, *Snohomish*  
Greenback Island, *Snohomish*  
Guler, northwestern *Klickitat*

Hadlock, *Jefferson*  
Hanford, *Benton*  
Harrington, *Lincoln*  
Hartford, *Snohomish*  
Hillyard, *Spokane*  
Holly, *Kitsap*  
Hoquiam, *Grays Harbor*  
Houghton, *King*  
Husum, *Klickitat*

Ilwaco, *Pacific*  
Index, *Snohomish*  
Indian Canyon, *Spokane*  
Joyce, *Clallam*  
Juanita, *King*  
Junction, *Jefferson*

Kalama, *Cowlitz*  
Kamiak Butte, *Whitman*, near  
Pullman  
Kennewick, *Benton*  
Kent, *King*  
Kerriston, *King*  
Keyport, *Kitsap*  
Kingston, *Kitsap*  
Kirkland, *King*  
Klickitat River, *Klickitat*

Lacey, *Thurston*  
LaConner, *Shagit*  
Lacrosse, *Whitman*  
Lake Bonapart, *Okanogan*  
Lake Chelan, *Chelan*  
Lake Crescent, *Clallam*

Lake Croker, *Jefferson*  
Lake Cushman, *Mason*  
Lake Keechelus, *Kittitas*  
Lake Park, *Pierce*  
Lake Parker, *Pend Oreille*  
Lake Quinault, *Grays Harbor*  
Lake Sawyer, *King*  
Lake Sullivan, *Pend Oreille*  
Lake Wiser, *Whatcom*  
Langley, *Island*  
Latah Creek, *Spokane*  
Lawton, Fort, *King*, near Seattle  
Liberty Creek, *Spokane*  
Licking, *Whatcom*  
Lind Adams  
Lofall, *Kitsap*  
Loomis, *Okanogan*  
Lucerne, *Chelan*

Mackay Harbor, *San Juan*  
Major Creek, *Klickitat*  
Manette, *Kitsap*  
Manor, *Clarke*  
Marietta, *Whatcom*  
Markham, *Grays Harbor*  
Marysville, *Snohomish*  
Medical Lake, *Spokane*  
Medina, *King*  
Metaline Falls, *Pend Oreille*  
Milltown, *Skagit*  
Mineral, *Lewis*  
Moclips, *Grays Harbor*  
Molson, *Okanogan*  
Monroe, *Snohomish*  
Montborne, *Skagit*  
Monte Cristo, *Snohomish*  
Montesano, *Grays Harbor*  
Mt. Adams (Mt. Padua) *Skamania*  
Mt. Baker, *Whatcom*  
Mt. Baldy, *Chelan*  
Mt. Chopaka, *Okanogan*  
Mt. Padua (Mt. Adams)  
Mt. Pleasant, *Clallam*  
Mt. Rainier, *Pierce*  
Mt. Vernon, *Skagit*

Napavine, *Lewis*  
Nesel River, *Pacific*  
Nespelem, *Okanogan*  
Newport, *Pend Oreille*  
Nisqually River, *Pierce*  
Nooksack, *Whatcom*  
Noon, *Whatcom*  
North Cove, *Pacific*  
Northwood Swamp, *Whatcom*

Oakesdale, *Whitman*  
Oak Harbor, *Island*  
Oakville, *Grays Harbor*  
Oceanside, *Pacific*  
Ocosta, *Grays Harbor*



- Olalla, *Kitsap*  
 Olga, *San Juan*  
 Olympia, *Thurston*  
 Olympia Marsh (Olympia Slough)  
*Skagit*  
 Olympic Mts., mostly in *Jefferson*,  
 partly in *Clallam* and partly in  
*Grays Harbor*  
 Oroville, *Okanogan*  
 Oysterville, *Pacific*  
 Palouse, *Whitman*  
 Paradise Valley, Mt. Rainier,  
*Pierce*  
 Parker Lake, *Pend Oreille*  
 Pasco, *Franklin*  
 Pendle, *Lewis*  
 Peter's Prairie, *Skamania*  
 Piedmont, *Clallam*  
 Pleasant Beach, Bainbridge Island,  
*Kitsap*  
 Pleasant Prairie, *Spokane*  
 Pomeroy, *Garfield*  
 Port Angeles, *Clallam*  
 Port Blakeley, Bainbridge Island,  
*Kitsap*  
 Port Discovery, *Jefferson*  
 Port Gamble, *Kitsap*  
 Port Ludlow, *Jefferson*  
 Port Orchard, *Kitsap*  
 Port Townsend, *Jefferson*  
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 Puyallup, *Pierce*  
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 Randle, *Lewis*  
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 Republic, *Ferry*  
 Rhodesia, *Pacific*  
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 Ritzville, *Adams*  
 Rochester, *Thurston*  
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 Spokane, *Spokane*  
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 Sullivan Lake, *Pend Oreille*  
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 Wapato, *Yakima*  
 Washtucna, *Adams*  
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 Wenatchee, *Chelan*  
 Westport, *Grays Harbor*  
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 Little White Salmon River, branch  
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 Willapa, *Pacific*  
 Winlock, *Lewis*  
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 Wiser Lake, *Whatcom*  
 Wishkah, *Grays Harbor*  
 Woodinville, *King*  
 Woodland, *Cowlitz*  
 Woodman, *Jefferson*  
 Wright, Fort, *Spokane*  
 Yakima, *Yakima*  
 Yarrow, *King*  
 Yelm, *Thurston*  
 Yeomalt, *Kitsap*

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